

Yak production in central Asian highlands

Proceedings of the Third International Congress on Yak held in Lhasa, P.R. China, 4–9 September 2000



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Edited by

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Preface

The yak, as the only bovine species adapted to the cold and harsh conditions of the Hindu Kush-Himalayan region and Qinghai-Tibetan plateau with an altitude ranged from 2000 to 5000 metres above sea level (masl), has been central to the development of the farming and the pastoral communities of these areas. The domesticated population is estimated to be around 15 million while wild yak are still present in the nature reserves in People's Republic of China.

The range of products and services provided by the yak is considerable, among others: wool and leather for clothing, shoes, blankets, bags, rugs and tents and bones for carving meat and milk as fresh and dried food, processed butters and cheeses for consumption, sale and ceremonial offerings; transport for trade and draft power financial assets (in case of accidents, wedding or others ceremonies etc.) and manure for cooking, heating, and nutrient recycling.

The Third International Congress on Yak was held from 4-9 September 2000 in Lhasa, Tibetan Autonomous Region (TAR) of P.R. China. More than 110 Chinese and 70 international delegates attended it. It was the third time that the congress was held in China, the most important yak rearing country, following the conferences in Lanzhou (Gansu, August 1994) and in Xining (Qinghai, September 1997). The congress was held successfully with strong supports of the Tibetan Government and relevant authorities. More particularly, the state ministries of Science and Technology, Agriculture and Foreign Affairs, the TAR Government, the Tibetan Academy of Agriculture and Animal Sciences (TAAAS), the Department of Agriculture and Animal Husbandry, the Department of Science and Technology, and the Foreign Affairs Office of the People's Government of Tibetan Autonomous Region worked efficiently for the preparation of the meeting with the full co-operation of the International Yak Information Centre (IYIC), the International Centre for Integrated Mountain Development (ICIMOD), the International Livestock Research Institute (ILRI), the Food and Agricultural Organization of the United Nations-Regional Office for Asia and the Pacific (FAO-ROAP), and the Yak and Camel Foundation of Germany. Financial supports were also given by the China Yak Breeding Association, Heifer Project International (China Office), Qinghai Academy of Animal and Veterinary Sciences, Datong Yak Farm, Kyrgyz Swiss Agricultural Project (KSAP), Helvetas Kyrgyzstan, Canadian International Development Agency (CIDA) and the Royal Netherlands Government Embassy in Beijing.

The proceedings includes the invited papers and research papers presented in both oral and poster sessions. Out of 122 presentations 86 are published here. We thank all contributors for their support during the reviewing and the editing processes of the papers. This proceedings is yours. We apologise for any mistake that might have gone through the reviewing process.

We would like to particularly thank Drs Nyima Tashi and Gerald Wiener for helping us in reviewing some of the papers. Last but not least, our gratitude goes to the ILRI

publications group, especially Ms Anne Marie Nyamu, Ato Tesfaye Jemaneh and Ato Mezgebu Abegaz, who tirelessly edited the final papers. Thanks again!

Editors

Special session

Towards a global approach to the study of yak research and development

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Introduction

The purpose of this yak conference is to explore multidisciplinary aspects and approaches to sustainable yak production on the high altitude rangelands of Central Asia. It is a unique opportunity to recapitulate past efforts concerning yak research and development (R&D), to summarise the accomplishments achieved in the different aspects of research, and to envisage future perspectives. Research and experiments related to yak rearing and pastoralism have only been undertaken recently. In the beginning, these studies were initiated in a few centres, mainly far from the 'field' and often ignoring local practices. We feel it is important to develop a 'global approach' to this research (from a methodological point of view) and to defend the need for more global-oriented research.

There are a number of variables, which relate to the climatic adaptation of yak to their environment. These include: 1) environmental conditions such as temperature, humidity, air circulation, heat, radiation and precipitation; 2) individual characteristics such as species, breed and type; and 3) physical criteria such as productivity, growth, reproduction, physical responses and pathological patterns.

Co-ordinated multidisciplinary research for animal production systems

The present approach to yak rearing is, in most of the cases, a 'linear analytical' approach, where each research topic is studied separately. Though each individual topic does require further research, it can also benefit from other lines of enquiry. We would like to present briefly the systemic approach that specialists in cattle rearing have developed in France, which we feel offers useful directions for present and future research related to yak rearing (Landais 1993; Landais and Bonnemaire 1996).

Animal production systems (or livestock herding systems in extensive yak breeding areas) are generally studied in terms of the complex interaction between three components (animals, humans and resources), which are linked by a set of interdependent and interrelated outputs (e.g. animal products, increase of herd, wealth, social position,

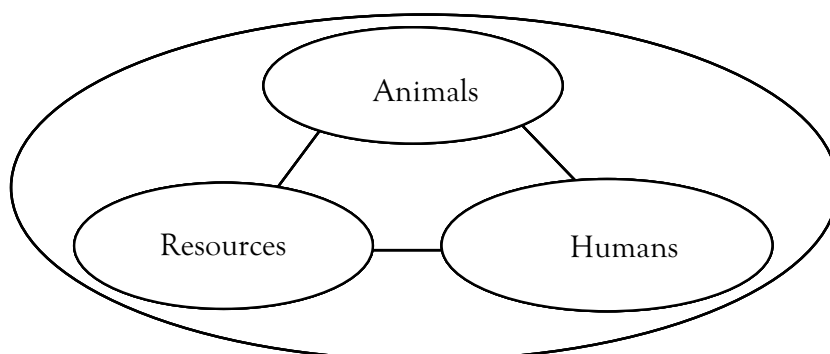
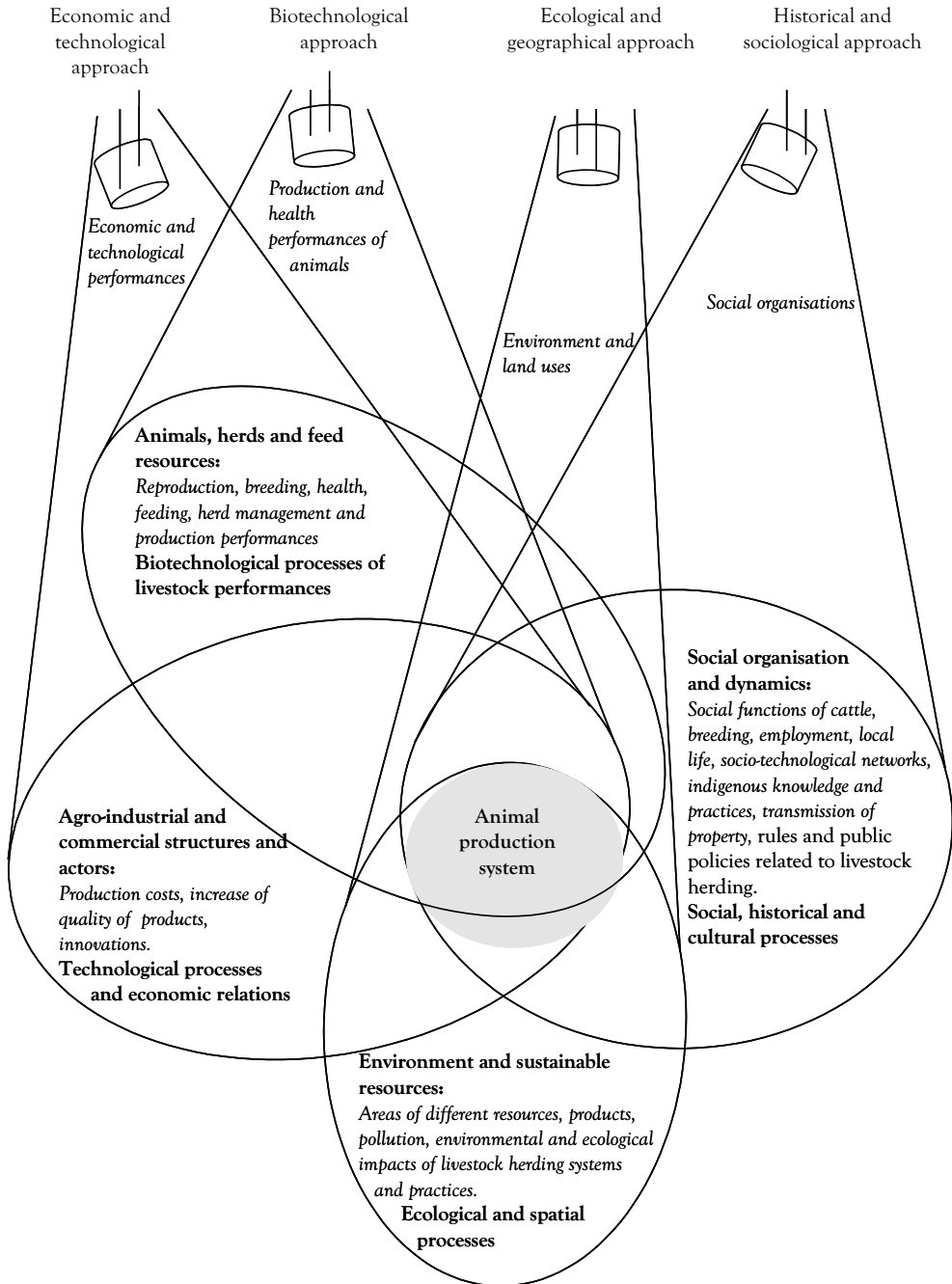


Figure 1. *Animal production system.*

sustainable land resource management etc.). This systemic approach to herding activities mainly focuses on the relations between the components of the system. This model of the animal production system (Figure 1) can be applied at different organisational levels (e.g. herd, family settlement, social group, ecological or regional area etc.).

Because livestock herding is fundamentally a human activity which takes place in a specific territory, four complementary approaches need to be taken into consideration when analysing animal production systems: The economic and technological approach, which considers both the subsistence and market economy; the biotechnological approach, which looks at the performances of both individual animals and that of the herd; the ecological and geographical approach, which takes into account the potential of fodder resources, sustainable land use and range management; and the historical and sociological approach, which considers social processes and social organisation. Each of the four complementary approaches mobilises specific disciplinary knowledge and methods, and focuses on some of the multiple relations that link the three components of the system. In other words, each point of view identifies research subjects that, taken together, help us advance our knowledge and understanding of problems related to livestock herding.

We present a graphic representation of an inter- and multi-disciplinary approach to the analysis of livestock herding systems (Figure 2). The figure presents the four major disciplinary approaches as spotlights whose beams converge on the central problem being studied, in this case the animal production system. Just as a camera is focused on an object to obtain a sharp image, the most effective interaction occurs where the four approaches focus their efforts on a specific problem of common concern. Applied to yak rearing, the process involves a number of main issues: e.g. the social organisation of the pastoral community, the indigenous skills and know-how of the people involved, and the technical knowledge needed to upgrade and transmit knowledge.



Adapted from Landais and Bonnemaire (1996).

Figure 2. Four complementary approaches for analysing the animal production systems.

Importance of yak research in marginal zones

Before ending, we would like to emphasise the importance of studying yak rearing in marginal zones (by 'marginal zones' we mean the areas on the fringe of the main yak breeding areas, i.e. parts of Mongolia, the ex-Soviet Union states in Central Asia and the Himalayan belt). These zones are of special interest for several reasons. In these 'marginal' areas, diverse categories of animals are bred, such as bovines (*Bos taurus*, *Bos indicus* and *Bos grunniens*) sheep, goats and horses, as part of a complimentary system of economic production. It also happens that many of these areas have, in recent years, created protected areas such as parks (regional or national parks) and nature reserves. The decision makers in charge of protecting the environment (a concept which was relatively unknown a few years ago by local inhabitants) have taken measures, which, in many cases, have perturbed the life of farmers and pastoralists living in these areas. In addition, in many of these areas, the communities are more and more being exposed to market forces, management systems and outside interventions, which positively or negatively alter the life of the farmers/pastoralists living there. Tourism, often only recently introduced, can also change the ways of life of these communities.

If we may, we would like to emphasise the importance of conducting fundamental research in these areas closely related to a sound sustainable development process. The link between pastoralists, specialists-technicians or scientists in livestock management and animal husbandry, decision makers and actors in the economic and administrative sectors, and the media, should be further encouraged.

As a final remark to this short overview, we would like to re-emphasise the absolute necessity of the circulation of relevant and up-to-date information. If the internet is of help, the more the better, but it is also important to disseminate knowledge through more conventional channels, such as the regular publication of the International Yak Newsletter and the publication of results of experiments both in laboratories and in the field. In this regard, the efforts undertaken by the International Yak Information Centre (IYIC) team are fully acknowledged and further encouraged.

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The potential for rangeland development in yak-rearing areas of the Tibetan Plateau¹

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Summary

Rangelands of the Tibetan Plateau are more than just a resource to sustain livestock. This region is an ecological and cultural landscape that fosters a rich diversity of human interactions within a complex socio-political and biophysical environment. This paper initially highlights the general characteristics of rangelands and pastoral production systems of the Tibetan Plateau. Given the realities of life in such a heterogeneous and marginal environment, the issue of secure resource tenure, both customary and legal, is fundamental for effective rangeland management. Using examples from the eastern Tibetan Plateau, the paper discusses important policy changes that have affected resource tenure and the positive and negative impacts these changes have had on the lives of pastoralists and the environment in which they live. We argued that a simple shift in tenure from the communal (traditional and subsistence) to individual household level (ranching and commercial) would not be enough to facilitate a change in behaviour toward 'rational' livestock operations. Many institutional mechanisms must be in place, including those that: 1) achieve economy of scale in operations (including means to manage pastures in communal groups); 2) ensure against disasters; 3) facilitate timely marketing and off-take; 4) protect commercial interests; and, 5) promote collective action to soundly manage larger landscape amenities. Promoting and building such institutional mechanisms takes time for commercial ranching to work well, a socio-economic environment that is far from the current reality on the Tibetan Plateau. In conclusion, the paper highlights certain pastoral-friendly policies that may facilitate a slow and sustainable trend towards market-oriented enterprises on the Plateau.

Keywords: Landscape heterogeneity, pastoral friendly policies, privatisation, subsistence economy, tenure

Introduction

Rangelands of the Hindu Kush-Himalayan (HKH) region, primarily located on the vast Tibetan Plateau, are much like rangelands of other parts of the world. They are a marginal resource, naturally low in productivity and diverse in character in terms of both precipitation and forage availability. They also represent a diverse cultural landscape,

1. Sections of this paper have been previously published in Richard (2000).

concurrently shaped by physical forces and human use. In this context, it is important to view rangelands as something more than just a resource to sustain livestock, but rather as a complex environment with a diverse array of amenities and possibilities, and a rich cultural milieu. In total, rangeland resources encompass approximately 2 million km² or over 60 % of the HKH region (Miller 1995), and are managed as a common property resource by millions of farmers and pastoralists.

The rangelands of the Tibetan Plateau are important for a number of reasons. For one they form the headwaters of the six major river systems of Asia. They comprise diverse ecosystems ranging from forest-alpine ecozones, high Himalayan alpine valleys rich with medicinal herbs, the vast basin and range alpine meadows of the eastern Plateau, to the high and dry alpine desert steppes of the western Changtang (Miller 1995). Much of this region offers important wildlife habitat² and many areas are now designated as protected areas with high potential for tourism development. Last, but certainly not least, these rangelands, especially the verdant pastures of the eastern Plateau, offer vast reserves of forage for grazing livestock, the products of which account for a significant percentage of the gross national product (GNP) of these areas (Wu 1997).

The quintessential animal among the domestic breeds of the Tibetan Plateau is domestic yak. The vast majority of the world's yak population resides in the eastern Tibetan Plateau of the Tibetan Autonomous Region, Sichuan, Gansu and Qinghai Provinces of China, which have the grassland resources to sustain relatively large numbers compared to the drier regions to the west. Despite their relatively low number compared to other livestock types in the western Plateau and the Himalayan, Karakorum and Pamir mountain ranges, they are no less important, providing important subsistence amenities such as fuel, meat, fibre, dairy products and transport across vast harsh terrain. Although domesticated 10 thousand years ago, the domestic yak has not genetically diverged greatly from its wild relative (Han Jianlin, personal communication, 2000), or even in grazing behaviour.

Domestication of this animal has led to the evolution of an extremely rich cultural heritage on the Tibetan Plateau. Culture is expressed in all facets of daily life: from religion and the arts to the way local communities manage their livestock and utilise resources. Therefore, when we talk of rangeland management, we must consider the importance of culture, as a base for future economic development in tourism, and by the manner in which particular ethnic groups perceive their landscape. This affects how particular commodities from, say, yak, will be produced, managed and marketed.

Characteristics of traditional pastoral production systems

Diversity and mobility characterise the pastoral production systems of this region. Pastoral production systems are diverse in order to minimise risk in unpredictable conditions. Pastoralists engage in multi-resource economies and usually maintain large, diverse herds.

2. Much of the region offers important habitat for many wildlife species such as blue sheep (*Pseudois nayaur*), kiang or Asiatic wild ass (*Equus kiang*), Tibetan antelope (*Pantholops hodgsoni*), which are rapidly being hunted to extinction for their fine underbelly hair called shatoosh, black necked crane (*Grus nigricollis*), and the endangered snow leopard (*Panthera uncia*), valued for its pelt.

Livestock products are, of course, the bases of subsistence, providing such goods as dairy products, meat, live animals for trade, wool, manure, fuel and labour. Pastoralists of the Plateau also engage in other economic and subsistence activities such as cropping, timber extraction, handicrafts for both tourism and local consumption, trade in manufactured goods and medicinal plant extraction, to name a few. Traditionally they have always been itinerant traders; modern opportunities have merely helped them to expand their networks.

It is also an ecological reality that livestock must be mobile to maintain rangeland health, the basis of extensive grazing systems. This is true whether one is talking about large arid rangelands or small intensively managed pastures. The mere difference is that, as the harsher the environment becomes, the further herders must move to acquire forage for livestock. Livestock mobility has been shown to be a good indicator of sustainable rangeland health (Sneath 1996), and can be compatible with biodiversity conservation (Wu and Richard 1999). If one can identify the factors that lead to changes in mobility, one can often address the causes of rangeland degradation. Factors that have led to a restriction of livestock mobility include: growing populations of human and livestock; expanding agriculture into the best quality rangeland areas; forestry or protected area initiatives that restrict grazing rights; government policies that promote settlement; and the changing aspirations of the pastoralists themselves. As elsewhere, the region is experiencing the growing pains of globalisation with new technologies, larger regional market economies, and aspirations for material wealth only attainable through cash income.

Given this rapidly changing context, there is certainly a need for improved rangeland management to meet the growing demand for forage in an increasingly commercial livestock economy. However, rangeland improvement schemes rely on continued capital investment and maintenance by livestock owners, which, in turn, only functions when there is secure access to various resources, such as pasture, water, credit and labour. Thus resource tenure becomes a fundamental aspect of effective rangeland management. Given this, a basic understanding of the types of tenure is necessary for the sake of this discussion.

Table 1 summarises the types of tenure that might exist in a given rangeland area. Tenure at its most basic level simply means a bundle of rights to control and access a particular resource or set of resources (Gilmour and Fisher 1991). Tenure is not merely ownership as commonly believed. Tenure can be legal or informal (and therefore sometimes technically illegal), private or public, common or individual. It involves those entities that make decisions and those who get the benefits from the resources and implies a dynamic process of negotiation. There are two points I wish to make from this comparison. First off, just because a particular rangeland pasture is used by a group of herders does not imply open access (or uncontrolled grazing). Many indigenous systems of communal management exist and operate effectively throughout the region. Second, many types of tenure can be simultaneously operating in the same area. If these tenure systems do not compliment each other, for example, state driven policies that privatise control of pastureland in an area previously managed communally, newly introduced rangeland management schemes are most likely to fail.

With this brief framework on the complexities of resource tenure, the question is raised as to whether fencing is the answer for improving rangelands of the Tibetan Plateau. As previously discussed, Tibetan Plateau landscapes are heterogeneous in terms of water and

Table 1. The types of tenure (rights to control and access resources) that can be operating in rangeland areas of the Tibetan Plateau.

Formal (<i>dejure</i> or legal)	Informal (<i>defacto</i> or customary)
State–land ‘owned’ by the government	(State control may not be recognised locally)
Individual–legal control by individual through lease or ownership	Individual–access by customary norm or rule
Common property–formalised through committees or co-operatives and sanctioned by the state	Common property–informal group norms and rules for control and access which may or may not be governed by local committees
(Open access not recognised legally by the state)	Open access–no rules or norms for access

forage availability, they are naturally low in productivity, and the vast majority of the local population still depends on diverse subsistence livelihood strategies. Given this context, a rapid shift from pastoralism³ to ranching might well have serious negative sociological and ecological consequences, as discussed below.

Impacts of China’s grassland law

This section focuses on policy changes in the eastern Tibetan Plateau, located in the Chinese provinces of Qinghai, Gansu and Sichuan. This region is undergoing drastic changes in land tenure, with settlement policies promoting the individualisation⁴ of rangeland stewardship as a means to mitigate the effects of the perceived ‘Tragedy of the Commons’.⁵ The Chinese government, citing the success of Deng Xiao Ping’s reforms of the early 1980’s, specifically the policy of Individual Household Responsibility System in cropping areas, formulated the Grassland Law in the mid-eighties, based on the assumption that grasslands of China were degrading due to lack of secure tenure and stewardship (Williams 1996; Thwaites et al. 1998).

The Chinese government offers sound rationale to justify settlement policies such as the Grassland Law. For one, it has been difficult to provide nomads with social services such as education and health care, and heavy snowfalls have historically lead to loss of livestock (Wu and Richard 1999). It was felt that fencing could help provide reserve pastures during these critical periods. However, underlying these justifications is a general lack of faith in traditional migratory grazing systems. Factors often mentioned are the ‘irrational’ structure of nomads’ herds, with too few breeding females and too many unproductive animals, and the consequent severe overgrazing and desertification due to lack of individual responsibility (Zhang 1989).

Although late to come to the eastern Plateau compared to other parts of China, implementation of the policy is happening rapidly. In the past few years, pastures have been

3. The term ‘pastoralism’ as used in this paper refers to traditional subsistence livestock rearing, usually herded in family groups, to distinguish it from ‘ranching’ which refers to commercial livestock rearing managed by an individual entity such as a household or co-operative.
4. The term ‘individualisation’ is used here in lieu of the term privatisation as the Grassland Law of China facilitates long-term leasing of land to individual households rather than land ownership.
5. A term coined in the now-much-refuted writings of Hardin (1968), perhaps the one theory to do more damage than any other with regards to rangeland tenure throughout Africa and now Asia.

allocated to individual households and large areas fenced to demarcate these boundaries. However, little effort has been made to monitor the impacts of such policies on either the environment, or the people most affected. The International Centre for Integrated Mountain Development (ICIMOD), in partnership with regional research institutes in the provinces of Qinghai, Gansu, Sichuan and Yunnan, has initiated participatory action research projects to evaluate the effects of such policies and to identify sustainable alternatives where needed.

Table 2 highlights the preliminary findings of these studies. Not all positive and/or negative characteristics are found in all studied sites. This table merely summarises some general findings. The actual situation reflects the local policies that have been adopted to implement the general guidelines of the Grassland Law. For example, in Hongyuan County, Sichuan, individual households cannot recombine individually allocated land that would help to facilitate economy of scale in operations. Meanwhile, in Maqu County, Gansu, local officials have allowed recombining of land, provided that households initially accept an individual allotment, a requirement for future government subsidies for rangeland improvements. Issues such as access to water and high individual household costs will more likely reflect situations similar to those found in Hongyuan where individual households borne all the burden of pasture management. More details of these studies will be forthcoming in publications by ICIMOD and partner institutions.

Table 2. Impacts of the Grassland Law through individual tenure and fencing.

Positive	Negative
Where fencing is used for reserve pastures, livestock mortality has been reduced	Poor allocation of pastures in many areas with some receiving good quality land and others poor land
Reduced labour for overall household, although the gap between men's and women's labour has increased as men no longer spend time in long-distance herding	Individual pastures are often too small forcing herders to liquidate herds or rent pasture from those with excess land
Serves as border protection which has reduced conflicts in some areas	Lack of water on individual pastures/lack of access to neighbour's water sources
Increased access to markets where fencing is used for constructing holding pens	Costs per household too high for improvements—high subsidies required by the government
Better access to veterinary care and other services	Degradation of surrounding 'commons'—no communal responsibility for landscape amenities such as riparian areas
Has forced herders to fix number of livestock (although this could reduce long-term flexibility under drought conditions)	Increased labour for children—as parents find time to seek employment in nearby towns, children now required to maintain herds and have lost opportunity to attend school
In some areas poorer households can combine their pastures which cuts cost to individual household	In other areas, households are not allowed to recombine, thus creating more economic hardship and reduction of herds

Sources: Field visits by author to Maqu County, Gansu, Dari County, Qinghai, and Hongyuan County, Sichuan, in 1999 and 2000; field study conducted by participants of a Participatory Rangeland Management training in Hongyuan, Sichuan, July 2000; Regional Rangeland Programme Annual reports by: Du and Zhang (2000), Ma et al. (2000) and Yan et al. (2000).

As these policies sweep the region, it is important to look at the situation for what it is—an attempt to convert a pastoral way of life to an ‘efficient’ ranching enterprise. This is based on the assumption that a simple change in land tenure will facilitate a shift from subsistence to market-oriented behaviours. However, the behaviour and rationale of pastoralists are dictated first and foremost by an awareness of the realities of the marginal landscape in which they live, a landscape that has sustained their way of life for centuries. A rapid conversion to a new mode of thinking cannot be done without resulting in substantial socio-economic and ecological consequences. To illustrate this point, I make a comparison between a western ranching operation (for example, from Colorado, USA, with a similar environment to the eastern Plateau) and Tibetan pastoralism (Table 3). This table is not meant to make a value judgement, such as one system being better or worse than the other type. It is mainly meant to show that, if ranching is to work well, the socio-economic context must be amenable to such a mode of operation, something that is far from the current reality on the Tibetan Plateau.

Table 3. *Tibetan Plateau pastoralism vs. a ranching operation in the Rocky Mountains of Colorado, USA.*

Tibetan Plateau pastoralism	Colorado ranching
Subsistence oriented, diverse products for home consumption with some surplus for sale	Commercial, single product oriented (e.g. Meat)
Majority of population engaged in pastoralism (livelihood necessity)	Very few ranchers with most people engaged in other economic activities (ranching is a lifestyle choice)
Several households have access to a large area which is communally managed	One operator has exclusive access to the same amount of area and livestock
<i>De facto</i> tenure (customary, common property)	<i>De jure</i> tenure (legal, individual)
Low capital and high labour investment	High capital investment—only larger operations are profitable
Risk averse, engage in multiple economic strategies	Risk-taking (insurance schemes and legal mechanisms to protect commercial interests)

Conclusions and recommendations

The potential for rangeland and pastoral development is vast, if certain pastoral friendly policies are put into place that facilitate a slow and sustainable trend toward market-oriented enterprises on the Plateau. Initial enterprise development should be based on the premise that animal husbandry and livelihoods on the Plateau are still subsistence-based and that the environment upon which these livelihoods depend is marginal, with limited potential for intensification. Given this, the following general policy guidelines are recommended for the Tibetan Plateau:

- Promote livestock mobility. Settlement of communities can work but livestock must stay moving to prevent environmental degradation. This is the basis of ‘scientific’ (and indigenous) pasture management.
- Promote economic diversification, keeping in mind that livestock cannot be a viable commercial enterprise for all those who currently depend on subsistence animal husbandry. We need to improve our efforts to provide education, vocational training

and credit to promote diverse industries and vocations to get people off the range so that those remaining can develop commercially viable and sustainable livestock operations.

- Initially reduce risk to the individual household by legitimising communal tenure and management of pasture resources so that those now dependent on the rangeland resource can have equitable access to resources. This should be accompanied with development of credit schemes and legal mechanisms to protect both individual and communal rights to resource access.
- Build social cohesion through collaborative management of rangeland resources, with local communities in partnership with government extension, research and administrative entities.
- Promote social and gender equity to ensure a fair livelihood base for all.

Only when we build on the strengths of local communities will we successfully achieve our collaborative goal of improving pastoral livelihoods through sustainable rangeland management. This requires a new way of thinking, a new approach that legitimises and embraces the diversity of knowledge among people, from the herder to the scientist and policy maker. This will only come about when there is first a willingness on the part of governments to promote more democratic mechanisms for research and development planning and implementation.

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Session I: Rangeland development

Climatic and grazing controls on vegetative aboveground biomass: Implications for the rangelands on the north-eastern Tibetan Plateau

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Summary

This study investigates how two cited causes of rangeland degradation—grazing and climate change—affect key ecological characteristics of the rangelands on the north-eastern Tibetan Plateau. In August 1997, we established experimental plots in two habitats: 1) a summer-grazed shrubland; and 2) a winter-grazed meadow. Within each habitat, we identified sites with low and high grazing intensity histories, within which we established a complete factorial experimental design. The treatments are: 1) simulated warming using open top chambers (OTC); 2) simulated grazing through clipping (G); and 3) combined warming and defoliation (OTC × G). In this paper, we present 1999 growing-season data on habitat, grazing history and treatment effects on vegetative aboveground biomass. Combining all sites, the growing-season-averaged air temperatures in the OTC and OTC × G plots were 1.28°C and 1.33°C warmer than the controls, respectively. Moreover, the chambered plots (OTC and OTC × G treatments combined) resulted in a 12% decline ($P = 0.07$) in total aboveground biomass. However, different trends emerge when the sites are grouped by grazing history. In the low grazing history sites, the defoliated plots (G and OTC × G treatments combined) had approximately 17% more total biomass compared to the non-defoliated plots. Conversely, in the high grazing history sites, the chambered plots had approximately 12% less biomass as compared to the non-chambered plots. Furthermore, the shrub sites were more responsive to the treatments as compared to the meadow sites. To relate these biomass changes to rangeland quality, we evaluate the compositional changes of different vegetative functional groups in response to our experimental manipulations.

Keywords: Climate warming, grazing, rangelands, Tibetan Plateau, vegetative biomass

Introduction

The Tibetan Plateau is widely regarded as a region where the traditional pastoral system, which has developed over millennia, still flourishes. Over 70% of the vegetation that covers 2.5 million km² of the Plateau is classified as ‘rangeland’ vegetation. In the relatively mesic and productive north-eastern portion of the Tibetan Plateau, the primary habitat types are alpine meadow and shrub vegetation; these habitats comprise approximately 35% of the total rangeland area occupied by the Tibetan Plateau (Zhao and Zhou 1999). The vegetation in this region provides relatively favourable forage for yak and sheep, the pastoralists’ primary livestock. However, as in most parts of the world, this region is facing a suite of perturbations—changes that may profoundly affect the natural vegetation that constitutes the foundation of this pastoral production system. The driving forces behind these modifications to the rangelands are varied—some may be attributed to natural phenomena and cycles; some result from human activities far beyond the margin of the Tibetan Plateau; and some of these changes may result from dynamics within the region itself.

One phenomenon that may be affecting the Plateau grasslands is a warming and drying trend. Direct field measurements (French and Wang 1994), ice core data (Thompson et al. 1989; Yao et al. 1997), and interviews with pastoralists over 25 years old living in the research area (unpublished data), all provide evidence of a warming trend on the north-eastern Tibetan Plateau. Concurrent with these climatic changes, over the past 10–20 years there have been changes to the pastoral land use dynamic due to agricultural development, land tenure and sedentarisation policies (Cincotta et al. 1992; Miller 1999b).

Researchers (Yang 1992; Miller 1999b; Limbach et al. 2000; Ma et al. 2000) and pastoralists have observed rangeland degradation in recent years on the Tibetan Plateau. Some researchers attribute this to overgrazing (Ma et al. 2000); others suggest that climate change may be responsible for these rangeland dynamics (Miller 1999b). The purpose of this paper is to present data from a study that is explicitly investigating how two cited causes of rangeland degradation—grazing and climate change—affect key ecological characteristics of the rangelands on the north-eastern Tibetan Plateau. Through controlled experiments, we seek to obtain a detailed understanding of climatic and grazing controls on ecological properties and processes on the north-eastern Plateau grassland system. Specifically, we are investigating how climate warming, historic and current grazing levels, and the interaction of warming and grazing affect various aspects of rangeland quality. In this paper, we present 1999 growing-season data on habitat, grazing history and treatment effects on vegetative aboveground biomass.

Methods

To address our research questions, in 1997 we established experimental plots at the HaiBei Alpine Meadow Research Station in Qinghai Province, China (located at 37°29’N, 101°12’E, with an average altitude of 3200 metres above sea level (m.a.s.l.), on the north-eastern portion of the Tibetan Plateau. Annual precipitation averages 500 mm, over 80% of which falls during the summer months. Mean annual air temperature is 2°C (Zhao

and Zhou 1999). We are working in two main habitats that are distinguished by the dominant vegetation and the traditional season-of-use by the pastoralists: 1) a summer-grazed, *Potentilla fruticosa*-dominated deciduous shrubland; and 2) a winter-grazed grassland. The grassland is comprised of a combination of sedges such as *Kobresia humilis*, perennial grasses such as *Elymus nutans* and *Stipa purpurea* and a suite of forbs, over 80% of which are perennial. Within each vegetation type, we identified sites with low and high grazing intensity histories for a total of four main study areas. Grazing histories of the sites over the past 10–15 years were reconstructed based on interviews with local herders whose families have lived in the region for several generations and with long-term researchers at the station.

Within each study area, we fenced off an area of 30 × 30 m, in which we established a complete factorial experimental design with four-fold replications. The treatments are: 1) warming; 2) defoliation; and 3) combined warming and defoliation (Figure 1). The heating treatment is achieved by setting up conical fibreglass open top chambers (OTCs), which are 1.5 m diameter and 40 cm in height. The fibreglass material has a high solar transmittance (86%) in the visible wavelengths and a low transmittance (<5%) in infrared radiation (Marion 1996). OTCs are the standard warming devices used by the International Tundra Experiment Program (ITEX) and are often used in remote locations to simulate climate warming (Marion et al. 1997; Oechel et al. 1998). Clipping plots to a height of 1–2 cm aboveground simulates grazing, while hand plucking shrub leaves simulate browsing. The grazing treatments at all sites simulate the amount of biomass removed by herbivores in the high grazed sites outside of the enclosed areas.

We report on habitat, grazing history and treatment effects on air temperature and aboveground peak biomass in the plots. In each plot we measure air temperature every hour over the growing season with HoboPro data loggers. Temperature probes are shaded from

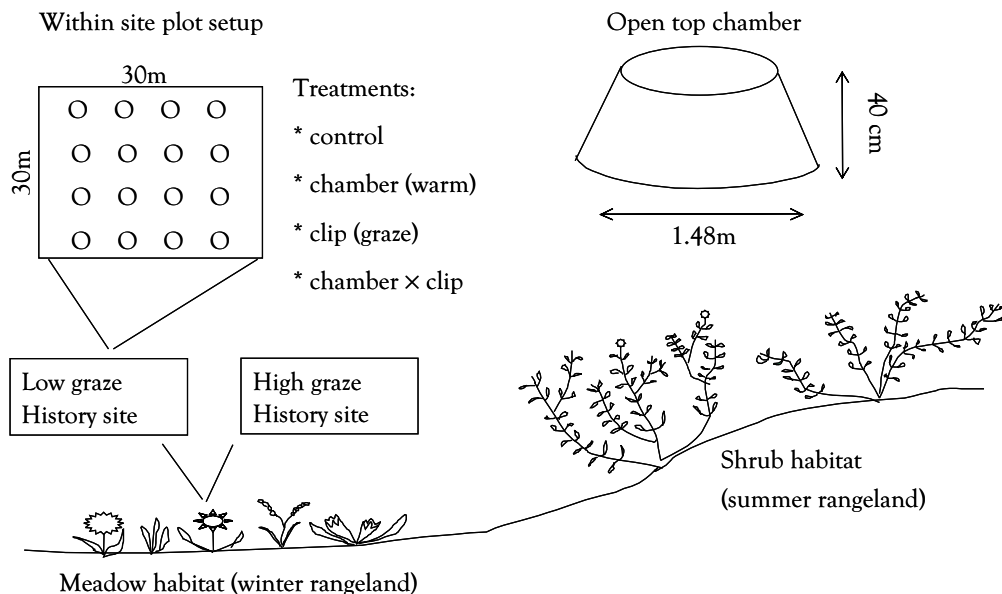


Figure 1. Experimental design.

direct sunlight exposure and are situated within 15 cm of the centre of the plots at 10 cm aboveground. Vegetation sampling occurs in a 75 × 75 cm grid centered in the plots. Non-destructive aboveground biomass sampling is achieved by measuring areal coverage every three weeks. Regression relationships between areal coverage and harvested aboveground dry biomass (B) off-plot in both habitats have been developed.¹ Peak biomass occurs when the converted areal coverage values reach a maximum over our sampling period; for the clipped plots, we add the removed biomass to the maximum measured values. Our primary statistical tool is analysis of variance (ANOVA) using SYSTAT version 8.0.

In this paper, we refer to the four study sites as follows:

- LGM = the low grazing intensity history meadow site;
- HGM = the high grazing intensity history meadow site;
- LGSH = the low grazing intensity history shrub site;
- HGSH = the high grazing intensity history shrub site.

We refer to the grazing history sites as follows:

- LG sites = low grazing intensity history sites in both the meadow and shrub habitats (LGM and LGSH combined);
- HG sites = high grazing intensity history sites in both the meadow and shrub habitats (HGM and HGSH combined).

We refer to the treatments as follows:

- C = control plots;
- G = clipped plots to simulate defoliation effects of grazing;
- OTC = plots with open top chambers to simulate warming;
- OTC × G = plots with both OTCs and clipping treatments.

Results

Air temperature effects: 1999 growing-season averages (June–September)

Habitat and grazing history control plot site comparisons: The control plots in the meadow sites were 0.80°C warmer ($P = 0.13$) than the control plots in the shrub sites. The controls in the HGSH site were 0.76°C warmer ($P = 0.15$) than those in the LGSH site.

Treatment effects: Combining all of the sites (Figure 2), the growing-season-averaged air temperature in the OTC and the OTC × G plots were 1.28°C ($P < 0.0005$) and 1.33°C ($P < 0.0005$) warmer than the controls, respectively. However, there was some variation in how air temperature at the individual sites responded to the treatments (Table 1).

1. Shrub biomass (B) = $-2.559 + 1.206 * \text{Areal coverage (AC)}$ (adjusted $R^2 = 0.941$, $P < 0.0005$); Meadow grass B = $-4.134 + 1.815 * \text{AC}$ (adjusted $R^2 = 0.954$, $P < 0.0005$); Shrub grass B = $11.672 + 1.177 * \text{AC}$ (adjusted $R^2 = 0.706$, $P = 0.006$); Forb B = $0.566 + 0.673 * \text{AC}$ (adjusted $R^2 = 0.829$, $P < 0.0005$); Sedge B = $0.269 + 1.248 * \text{AC}$ (adjusted $R^2 = 0.463$, $P = 0.12$).

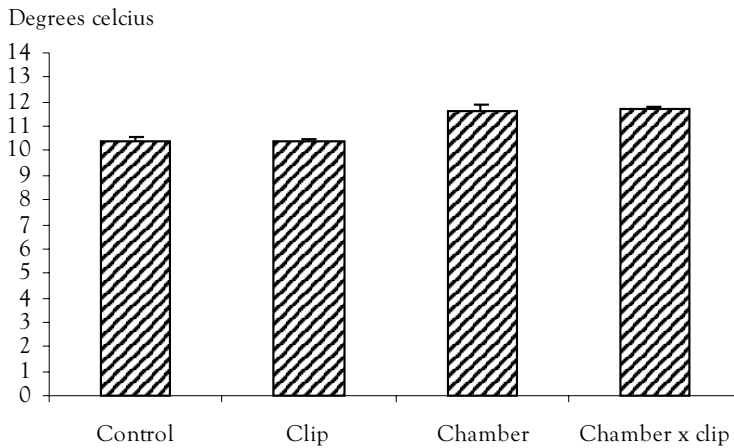


Figure 2. The 1999 growing-season-averaged air temperature with all sites combined.

Table 1. Treatment effects on season-averaged air temperatures in the four study sites.

Study sites	C	G	OTC	OTC × G
HGM	10.16 ± 0.38	10.13 ± 0.07	12.34 ± 0.10	11.43 ± 0.22
LGM	11.08 ± 0.04	10.19 ± 0.03	11.09 ± 0.09	11.95 ± 0.05
HGSH	10.58 ± 0.28	10.66 ± 0.09	12.55 ± 0.06	12.22 ± 0.12
LGSH	9.86 ± 0.15	10.56 ± 0.14	10.61 ± 0.01	11.39 ± 0.16

C = control plots; G = clipped plots simulating effects of grazing; OTC = open top chambers plots simulating warming; OTC × G = plots with Both OTCs and clipping treatments; HGM = high graze meadow; LGM = low graze meadow; HGSH = high graze shrubs; LGSH = low graze shrubs.

Values reported are means in °C ± standard error.

Aboveground biomass: 1999 peak biomass values

Habitat and grazing history control plot site comparisons: The total peak aboveground biomass values in the control plots of the four sites are illustrated in Figure 3. The control plots in the meadow sites have 94 g/m² more total biomass ($P < 0.0005$) as compared to the shrub sites. The LGM has 61 g/m² more total biomass ($P = 0.009$) as compared to the HGM; conversely, the LGSH has 38 g/m² less total biomass ($P = 0.003$) as compared to the HGSH.

Treatment effects—All sites combined: When all four sites are pooled, the aboveground peak biomass in the chambered plots (OTC and OTC × G treatments combined) was 12% lower ($P = 0.07$) than in the non-chambered plots (C and G treatments combined) (Figure 4). The biomass in the defoliated plots (G and OTC × G treatments combined) was not significantly different from that in the non-defoliated plots (C and OTC treatments combined). This suggests that when all sites are pooled, the chamber-induced effects of

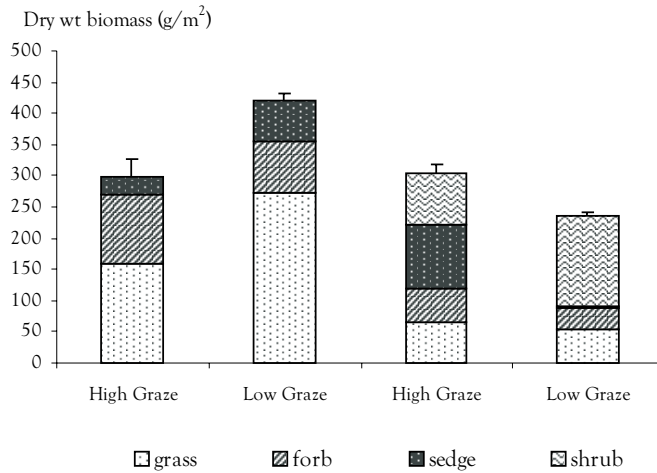


Figure 3. Total and functional group aboveground biomass comparisons among sites.

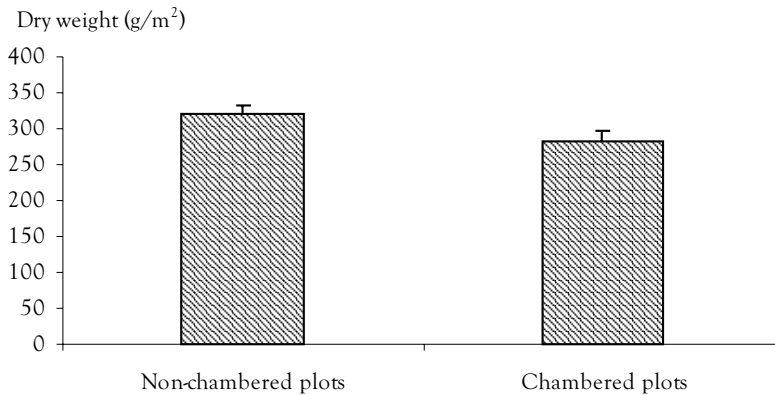


Figure 4. Effects of chamber treatments on total aboveground biomass with all sites combined.

warming are greater than the defoliation effects of grazing with respect to total peak aboveground biomass.

Grazing history comparisons: Different trends emerge when the sites are grouped by grazing history (Figure 5). In both high grazing history sites, there was a significant effect on total biomass of the chamber treatments (OTC and OTC × G plots combined) as compared to the non-chambered treatments (C and G plots combined). The chambered plots in the HGS_H had 62 g/m² less biomass ($P = 0.01$) and in the HGM had 62 g/m² less biomass ($P = 0.13$) as compared to the non-chambered plots. However, in both HG sites, the combined non-defoliated plots (C and OTC treatments) were not significantly different from the defoliated plots (G and OTC × G treatments). In the low grazing history sites, the defoliated

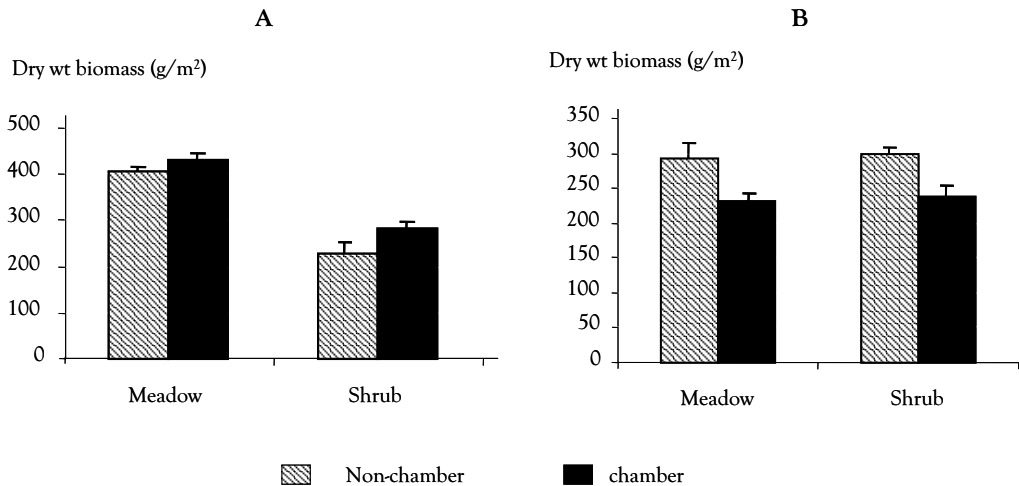


Figure 5. A. Low grazing history sites (LGSH)—effects of defoliation (G and OTC \times G plots combined) and non-defoliation (C and OTC plots combined) on total aboveground biomass. B. High grazing history sites (HGSH)—effects of chambers (OTC and OTC \times G plots combined) and non-chambers (C and G plots combined) on total aboveground biomass.

treatments had significantly more biomass as compared to the non-defoliated treatments. The defoliated plots in the LGSH had 58 g/m² more biomass ($P = 0.001$) and in the LGM had 23 g/m² more biomass ($P = 0.12$) as compared to the non-defoliated plots. However, there was no significant effect of the warming treatments on total biomass in the LG history sites. In both grazing history sites, the response of the shrub sites was greater in both magnitude and statistical significance than in the meadow sites.

Functional group peak biomass responses

Habitat and grazing history control plot site comparisons: Figure 3 illustrates the amount and relative proportions of peak forb, grass, sedge and shrub biomass in the control plots of all four sites. The meadow sites have 162 g/m² ($P < 0.0005$) more grass biomass and 51 g/m² ($P < 0.0005$) more forb biomass than the shrub sites. The combined LG sites have 46.37 g/m² ($P = 0.005$) more grass biomass, 24.78 g/m² ($P < 0.0005$) more forb biomass and 31.19 g/m² ($P = 0.001$) less sedge biomass than the HG sites.

Treatment effects

Forbs: One consistent result across all sites was that forb biomass increased with the defoliation treatments, not considering if they were warmed or not. When all sites are pooled, the combined defoliated plots had 29% ($P = 0.01$) more forb biomass than the non-defoliated plots (Figure 6).

Grasses: When there was a response of grass biomass to the treatments, the defoliation treatments stimulated grass biomass while the chamber treatments depressed grass biomass. In both shrub sites, the grass biomass was significantly lower in the OTC plots as compared

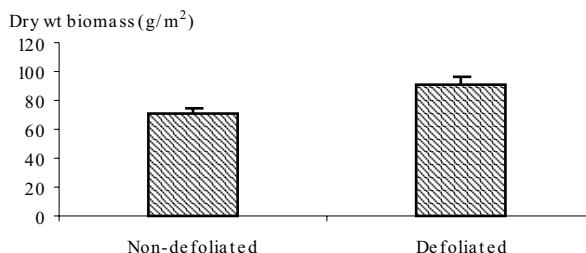


Figure 6. Effects of defoliation on forb biomass with all sites combined.

to their respective controls (30%, $P = 0.11$ decline in the HGSH; 73%, $P = 0.001$ decline in the LGSH). In the HGSH site, the G treatment resulted in 66% more grass biomass than the C treatment ($P = 0.016$). The OTC \times G treatment resulted in 62% ($P < 0.0005$) more grass biomass than the controls and 131% ($P < 0.0005$) more grass biomass than the OTC treatment. In both LG sites (meadow and shrub sites), the G plots had more grass biomass than the OTC \times G plots (18%, $P = 0.05$ more in the LGM; 70%, $P = 0.004$ more in the LGSH).

Sedges: In the HGSH and the LGM sites (the two sites with the greatest amount of sedge biomass), the chamber treatments each resulted in significantly less sedge biomass as compared to the controls (HGSH 70%, $P < 0.0005$ decline; LGM 38%, $P = 0.05$ decline).

Shrubs: The relatively consistent patterns noted above—negative biomass responses to the chambers and positive biomass responses to the defoliation treatments—do not hold with respect to shrub biomass. In the HGSH site, the G plot had 53%, $P = 0.01$ less shrub biomass than the C plots and 60%, $P = 0.001$ less biomass than the OTC plots. Moreover, the OTC \times G plots in the LGSH had 53%, $P = 0.002$ more shrub biomass than the controls and 51%, $P = 0.003$ more biomass than the OTC plots. The OTC \times G plots in the HGSH sites had 25%, $P = 0.05$ less shrub biomass than the controls and 36%, $P = 0.018$ less shrub biomass than the OTC plots.

Discussion

Air temperature

Habitat and grazing history control plot site comparisons: At 10 cm aboveground, the valley bottom meadow sites are marginally warmer than the shrub sites, which are approximately 40 m higher in elevation than the meadows and situated on a NW facing slope with moister soils. The HGSH sites were marginally warmer than the LGSH sites. This

could be due to the higher cover of shrubs at the LGSH which tend to keep the temperatures under its canopy cooler than those not under the shrub canopy.

Treatment effects

Grazing history: The air temperature in the HG sites responded more strongly to the OTC treatments as compared to the LG sites. The HGM has both less total peak biomass and drier soils as compared to the LGM. Moreover, the higher cover and amount of shrub biomass in the LGSH may partially mitigate the amount of warming experienced 10 cm aboveground and maintain moister soils as compared to the HGS site.

Within sites: Within both LG sites, the OTC × G treatments tend to result in slightly higher temperatures than the OTC treatments. At any given time, the amount of standing biomass (maximum converted areal coverage values without the addition of the clipped biomass) was lower in the OTC × G plots as compared to the OTC plots. Harte et al. (1995) found that both vegetative biomass and soil moisture status affect the magnitude of warming expressed at different sites in response to warming manipulations.

The above results suggest that current and historic grazing intensity may affect the expression of warming experienced at the sites. For a given downward flux of infrared radiation, the amount of warming may be greater at sites with a higher historic and current amount of grazing. Since our results indicate that warming tends to further reduce the biomass in these HG sites, this could constitute a positive feedback to warming.

Total aboveground biomass

Treatment effects

All sites: When all sites are grouped together, the combined chamber treatments resulted in less biomass as compared to the non-chambered treatments. This could be due to decreased growth in response to warming and/or reduced soil moisture availability. Alternatively, the warming treatments may have an indirect effect on biomass. In June 1999, the amount of litter accumulated in the chambered plots was significantly greater (65% more; $P < 0.0005$) than that in the non-chambered plots. This increased litter biomass could hinder plant establishment and growth.

Habitat comparisons: In terms of total biomass response to the treatments, the shrub sites were more responsive to the chamber and defoliation treatments as compared to the meadow sites. This suggests that the total aboveground biomass of the meadow sites might be more resilient to warming and grazing as compared to the shrub sites. The meadow sites may be less responsive to the defoliation treatments as the timing of our clipping treatments simulates the actual timing of grazing in the winter-grazed meadows; we clip the biomass prior to the onset of the growing season. However, this is a relevant finding in light of the different land tenure and season of use patterns between the meadow and shrub sites. Over the past 10–20 years, the winter-used meadow pastures have been allocated to individual households; fencing of these lands serves to demarcate property boundaries and to exclude

other livestock from grazing on these individually held parcels. These changes can result in increased grazing pressures on the summer grazing lands (Williams 1996). This increased grazing pressure would occur in the shrub habitat—the vegetative community that our results suggest maybe more vulnerable to the effects of warming and grazing.

Grazing history comparisons: In both low grazing history sites (meadow and shrub), the defoliation treatments result in more total aboveground peak biomass than the non-defoliated treatments. This could be evidence of biomass overcompensation, at least in the short-term. Dyer et al. (1993); Turner et al. (1993) reported that grazing increases, decreases or has no net effect on aboveground productivity in other systems. This is a highly controversial area of ecology and rangeland science (Maschinski and Whitham 1989; Painter and Belsky 1993; McNaughton et al. 1997). The outcome depends on a suite of factors, such as climatic conditions, evolutionary history of grazing, and the timing, intensity and frequency of grazing (Milchunas and Lauenroth 1993; Turner et al. 1993). Our short-term (<5 years) results suggest that when grazing is removed, as it is in our control plots, litter tends to build up. The presence of a substantial litter cover in the LG control plots may cause shading, which, in turn, reduces plant performance. Thus, defoliation of the vegetation, including removal of litter (yak and sheep consume senesced vegetation during the winter months), enhances peak total biomass relative to non-defoliated plots. Furthermore, the LG sites may have more reserves stored belowground. Thus, defoliated plants can reallocate belowground reserves to increased aboveground growth. The litter present in June 1999 in the control plots of the HG sites (32 g/m^2) is substantially lower than that in the LG sites (167 g/m^2). This smaller amount of litter may not hinder plant establishment and growth; moreover, plants with a higher grazing intensity history may not have the belowground reserves to overcompensate in response to defoliation.

Thus, our results suggest that, at least in the short-term, some amount of grazing may enhance aboveground biomass on the north-eastern Tibetan rangelands. Eliminating grazing from some sites may result in litter accumulation and reduced biomass production. However, with long-term heavy grazing, the rangelands may lose their ability to overcompensate for grazing. Our results suggest that, in the short-term, the sites with high grazing intensity histories can at least equally compensate for the total biomass removed by grazing.

In the HG sites, the combined chamber treatments elicited a stronger total biomass response than the combined defoliation treatments. In the LG sites, the defoliation treatments elicited a stronger total biomass response than the combined chamber treatments. This finding reveals that the effects of climate warming and grazing depend not only on habitat, but also on the land use history of the site. Sites that have higher grazing histories may be more susceptible to the effects of warming as compared to lower grazing history sites. In our study sites, over the short-term, the warming treatments reduced total biomass as compared to the non-warmed plots. Moreover, sites with a low grazing history may be more responsive to shifts in grazing practices as compared to sites with a high grazing history. In our study sites, over the short-term, the defoliation treatments increased total biomass as compared to the non-defoliated plots.

Functional group aboveground biomass

The observed resilience, with respect to total aboveground biomass, of the meadow habitat to our experimental manipulations may in part be explained by compensatory biomass responses of the different vegetative functional groups in the meadow. For example, in the OTC × G plots of the LGM site, forbs increased while sedges decreased by a similar amount. Several studies that have examined climate warming effects on vegetative biomass have observed this compensatory growth among different functional groups that result in no net change at the total biomass level (Chapin et al. 1995; Harte and Shaw 1995).

A consistent response across all sites was that forb biomass increased with the defoliation treatments. This finding is relevant to the issue of rangeland sustainability on the Tibetan grasslands. Some researchers are concerned that increasing forb biomass may enhance small mammal activity, which can contribute to rangeland degradation (Yang 1992; Ma et al. 2000; Smith and Foggin 2000). Moreover, some forbs are important medicinal plants and contribute to the pastoralist livelihood.

In the LGSH sites, the defoliation treatments increased total biomass relative to the non-defoliated plots. For example, in the LGSH site, the G plot and the OTC × G resulted in significantly more biomass as compared to the controls. This could be evidence of biomass overcompensation, especially under the conditions of warming. However, in relating these biomass changes to rangeland quality changes, we must consider not only the direction and amount of biomass change, but also the composition of that biomass. Most of the increase in total biomass in the LGSH was due to enhanced shrub biomass. In fact, grass biomass decreased in both the OTC and the OTC × G plots. Our analysis reveals a negative correlation between shrub and grass biomass (Pearson correlation coefficient = -0.78). Sheep browse the deciduous shrubs in the region, but the yak and horses do not consume the shrubs as forage. Therefore, an increase in shrubs might be favourable for sheep, but would not benefit yak or horses, especially if it entails a concurrent decrease in grass biomass. Thus, the impact of this compositional change in vegetative biomass depends on the pastoralists' herd composition, which is quite variable from region to region on the north-eastern Plateau (Miller 1999a). Moreover, since the shrubs commence growth and flower earlier in the season than most of the grasses, this shift in compositional biomass may be favourable in providing more abundant forage earlier in the season. However, it might also encourage the pastoralists to move onto the summer-grazed shrublands earlier in the season, with further implications for the shrub habitat. Finally, in the HGS site, total biomass decreased in response to the OTC treatment due to the significant decreases in graminoid species, clearly a negative effect for the grazing herbivores.

Aboveground biomass is important as the primary source of forage for both domestic and wild animals, as medicinal goods, fencing and other amenities. Moreover, aboveground biomass has important indirect effects on rangeland quality. The vegetation that is not removed by the secondary consumers in the system decomposes and contributes to the soil organic matter pool. The organic matter status of the soil affects both the fertility and water-holding capacity of the soil (Tisdale and Oades 1982). Our future papers will report on the soil organic carbon and nutrient availability status of our study sites and how they respond to our experimental manipulations.

Closing remarks

This initial analysis of the effects of climate warming and grazing on vegetative aboveground biomass suggests that the winter-grazed meadow sites may be more resilient to these factors as compared to the summer-grazed shrub sites. This resilience may be partially attributed to compensatory biomass growth of different functional groups that stabilises the total biomass responses to our experimental treatments. Moreover, the meadow resilience may also be partially attributed to the timing of defoliation events in the winter-used meadows. Aggregating the data from all sites, the warming treatments resulted in decreased total aboveground biomass. However, the responses to warming and grazing were strongly mediated by habitat type and grazing history. The sites with a high grazing intensity history may be more responsive to warming, whereas sites with a low grazing intensity history may be more responsive to grazing. Our LG history sites provided evidence of biomass overcompensation in response to defoliation, at least in the short-term. However, it is important to understand the compositional changes in biomass and how they will affect rangeland quality.

This paper represents an initial analysis of data from a more comprehensive study. For example, in this paper, we report on the air temperature effects of our treatments—but we are also monitoring soil moisture and soil temperature in all of our plots. Thus, future analyses will help us to discern whether the results we have reported above are due to the direct air warming effect of the treatments or to other indirect effects of warming—such as alterations in soil moisture availability. In addition, we have measured other outcome variables over multiple growing seasons that will provide further insight into our research questions. Moreover, we have only reported treatment effects on growing-season-averaged air temperatures for 1999. Growing season temperature averages may mask important treatment temperature differences over critical growth periods in the life cycle of the vegetation and of the grazing animals. For example, in May 2000 in the LGM site, the air temperature for the OTC plots were 1.79°C warmer than the controls ($P < 0.005$). However, our season-averaged 1999 air temperature data for the LGM reported above do not show any significant changes in air temperature due to the OTC treatment in that site. Finally, we are currently sampling over a larger area both to examine how representative our study sites are of other sites in the region and to relate to our results to a broader spacio-temporal scale.

Despite the limitations and the ongoing nature of our research, we hope that the preliminary findings reported in this paper will enhance our understanding of ecosystem dynamics in the region and contribute to the debate concerning the health and functioning of the Tibetan rangelands. While many people think of the region as remote and set off in traditional ways, the Tibetan Plateau region is facing contemporary challenges of the modern world—from development pressures to global climate change. It is imperative to work both within and beyond the borders of the Tibetan Plateau to address the driving forces behind these perturbations. However, it is also important to recognise these challenges and to obtain a basic and comprehensive understanding of the ecological dynamics in the region to help maintain the rangelands and pastoral lifestyles in the face of these prevailing changes.

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Yak grazing and forest dynamics in Sagarmatha National Park, Nepal¹

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Summary

Livestock grazing in forest sets off the alarm for resource managers who understand grazing to be incompatible with trees. Particularly in protected areas, livestock are targeted for restriction and removal because of the popular perception that forest grazing damages trees and inhibits regeneration, leading to degradation. However, a small-scale study of forest dynamics in Sagarmatha (Mountain Everest) National Park, Nepal, documents active regeneration in yak-grazed plots of *Abies spectabilis* woodland near Sherpa villages, and supports an interpretation of warm-slope vegetation as a diverse and enduring shrubland, not degraded forest. These findings challenge much of the received wisdom about the dynamics of Himalayan forests in general and those of the Mt Everest region in particular, and suggest that yak and yak-cattle hybrids here have been unfairly targeted as agents of forest destruction. Sherpa people have managed livestock to increase their spatial and temporal distribution, reducing their impacts. Tourism has accelerated the erosion of traditional grazing management, but this is not yet manifested to damage forests.

Keywords: Forest grazing, Mountain Everest National Park/Khumbu, resource management, yak

Introduction

Sagarmatha National Park (SNP), a 1110 km² reserve on Mt Everest's south flanks, encompasses not only the world's highest mountain and its spectacular sister peaks, but also the lower valleys of Khumbu, homeland of the Sherpa people. The Sherpa, famous for exploits on Everest, continue to live within the park. They retain claim to private lands within the national park's boundaries, but find themselves subject to a variety of regulations brought about by the expectations and priorities of the park's visitors and managers.

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In common with many mountain peoples, their traditional way of life depends on a variety of subsistence strategies including agriculture, trade and yak keeping. Their diversified subsistence exploits a variety of resources distributed along an extraordinarily long altitude gradient (more than 3000 metres between lowest and highest settlements), and provides what has been a sustainable way of life characterised by flexibility and resilience in a high-risk, high-altitude landscape. Yet Sherpa lives must constantly readjust to shifts in the expanding and volatile tourist economy and to ever-evolving policies for park management. The resilience of both people and landscape is being tested by the last few decades of accelerating change. The region's forest resources in particular were considered threatened by human use, and activities believed to damage woodlands, including wood cutting and livestock grazing (Blower 1971; Mather 1973; Mishra 1973; Lucas et al. 1974; Speechly 1976), were curtailed when the park was established in 1976 (Garret 1981).

Management of the park's resources in the years since has continued to be preoccupied with trees (Drew and Sharma 1977; Halkett 1981; Hardie et al. 1987; Ledgard 1989; Ledgard and Baker 1990). Rules promulgated by the park spell out where village fuel and construction wood may be gathered, restrict the kinds and movements of livestock, and promote the establishment of nurseries and plantations. This arbour-centric management persists despite a growing uncertainty about the status of the area's forests (Houston 1982; Thompson and Warburton 1985; Byers 1986; Ives and Messerli 1989; Stevens 1993), and in the face of continuing local resentment about the infringement of accustomed access to resources (Halkett 1981; Brower 1983; Brower 1987; Brower 1990; Stevens 1993). Khumbu's forests were initially assumed to be degraded remnants of formerly uninterrupted woodland covering all slopes and aspects below about 4100 metres above sea level (masl) (Naylor 1970; Stettler and MacDonald 1982 (unpublished data); Hardie et al. 1987), severely diminished in recent times by the collective assault of local people and swelling ranks of tourists (Blower 1971; Mishra 1973; Lucas et al. 1974; and Hardie et al. 1987). There are, however, questions about the extent of former forest, the time of deforestation, and the role of humans and livestock in the present patterns of forest cover (Brower 1987; Byers 1987a; Brower 1991a; Stevens 1993; Dennis and Brower 1995; Sherpa 1999).

In this paper we review the ideas and evidence that have accumulated about vegetation dynamics in SNP, and offer additional information in the form of our own study, an analysis of forest dynamics in the neighbourhood of Khumbu's main settlements. Our study refutes the conventional wisdom about a recently accelerated retreat in SNP forests. It affirms other work that argues against their declining status, challenges assumptions about the impact of grazing, suggests a new role for early human settlement in shaping the present pattern of forest and shrubland, and provokes a set of questions about forest interpretation and management. Our object is to augment the emerging picture of people-livestock-forest interactions in SNP, to warn against the use of unsupported intuition as a guide to resource management, and to argue for conservation policy that draws on both social and natural science, favouring neither and recognising the limitations of both.

The case of Sagarmatha

The history of environmental research and park planning and management in SNP reflects the increasing understanding about the interactions of culture and environment that has developed over the last twenty years. The importance of long-term human use in shaping 'natural' environments has grown, as has the awareness that successful protection of national parks and reserves requires the support and collaboration of people whose lands and resources are singled out for protection. SNP is especially intriguing for a number of reasons. This is one of several areas in the Himalaya where misgivings about conventional explanations for ecological processes first took root among researchers whose findings were at odds with expectations. Uncertainty on this Himalayan scale (Thompson et al. 1986) was of sufficiently high profile that researchers elsewhere took note, beginning to explore anew what had been considered settled questions about man's role in changing the environment. The intensity of attention that has been paid to the place, since Nepal opened its borders to the West 55 years ago, is perhaps unprecedented. When Everest was identified as earth's highest peak in 1854, it was marked as special and ensured the interest and attention of hosts of adventurers from all over the world.

Tourists have visited the area in tens of thousands, drawn both by mountain spectacle and challenge and by exotic culture. Development specialists have come to reforest; to tend both Sherpa and foreigners' health needs; to educate; to improve livestock; to initiate hydroelectricity at various scales; to monitor geomorphic processes; and to bolster indigenous culture and institutions. Scholars, too, have been very busy in SNP/Khumbu. Geographers, anthropologists, geologists, foresters, ecologists, biologists, and others have studied and written about the region, producing everything from magazine pieces based on a two-week trek to substantial books grounded in many years' abode. The long-term interest and deepening familiarity of a number of commentators provide insight, too, into the evolution of understanding about the workings of people and environment here (von Haimendorf 1964; Hillary 1964; von Haimendorf 1975; Ives 1979; Brower 1982; Brower 1983; Stevens 1983; von Haimendorf 1984; Brower 1987; Stevens 1989; Brower 1990; Brower 1991a; Brower 1993; Adams 1996; Brower 1996). In addition to these visitors, there is a significant voice of Khumbu-born Sherpas themselves, writing either in their role as young scholars trained in the West (Sherpa 1979a; Sherpa 1979b; Sherpa 1982; Sherpa 1987; Sherpa 1988; Sherpa 1993; Sherpa 1999) or as representatives of older Sherpa traditions (Tengboche Rinpoche and Klatzel 2000). All these eyes and voices mean a wide array of interpretations of the landscape of Khumbu/SNP.

Forests and grazing

This is perhaps nowhere better illustrated than by outsiders' perceptions about forest dynamics and the presumed role of livestock in deforestation. People who have commented about the state of Khumbu's forests include pleasure-seekers, adventurers, journalists, scientists and government agents. Some are passing through, others stop to study; each brings the preoccupations and perceptions of a particular point of view. Their

understandings of what they witness, reported in casual accounts, news reports, scientific journals, and government studies, have shaped a public understanding of the interaction between local people and wildland resources that has determined national and international policy regulating the use of lands and resources in SNP.

One such perception, widely shared and popularly circulated, sees Khumbu's forest history as a piece with the supposed pattern of gradually worsening human-induced deforestation hypothesised for the Himalaya as a whole:

The problem of the Himalaya . . . can be stated very simply. In an already high energy environment, rapidly accelerating human pressures over the last 50 years are exponentially augmenting massive and rapid transfer of large volumes of material downslope overcoming, at least in part, Nature's counteracting force of slope afforestation. The counteracting forces of nature, the natural plant associations, and the hitherto reasonably well balanced agricultural associations are being disrupted; soil fertility is being reduced; and whole hillsides are being lost to productive human endeavor (Ives 1979).²

This regional scenario, with its sense of crisis and implicit call to action, has been widely reviewed and refuted (Thompson and Warburton 1985; Ives and Messerli 1989; Metz 1991). It nevertheless persists as the guiding vision for Nepal's environment. The Khumbu variant of the scenario compounds the resource demands by the local population with the added impacts of tourists, who demand fuel wood and other products (Blower 1971; Mather 1973; Mishra 1973; Lucas et al. 1974; Bjonness 1979).

It has long been assumed that the arrival of the first Sherpa settlers, who came to Khumbu perhaps 25 generations ago, initiated a process of landscape transformation that began to accelerate in the last few decades under pressure from increasing numbers of visiting tourists. The subject of the history and environmental implications of Sherpa settlement in one part of Khumbu/Sagarmatha are explored in the brilliant doctoral dissertation of Sherpa (1999). The most frequently decried manifestation of human presence is the reduction in forest, ascribed to a spectrum of factors usually including tree felling and livestock grazing:

The forests and alpine scrub-grasslands of the park have been extensively modified and severely depleted. Apart from inaccessible country or country of colder aspect, elsewhere the forest is under pressure from human exploitation and stock-grazing, causing both a deterioration and diminution of area (Halkett 1981).

For Khumbu, as for the whole Himalaya, work in the last decade has forced a re-evaluation of the crisis scenario. Repeat photography (Houston 1982; Byers 1987a), forest analysis (Stettler and MacDonald 1982 (unpublished data); Byers 1987c; Jordan 1993; Sherpa 1999), oral history (Stevens 1993) and range analysis (Brower 1987) all suggest

2. Examples from among the earlier writings of several of participants of this conference could also serve to illustrate how pervasive and persuasive the 'Theory of Himalayan Degradation' was: 'A number of widespread practices—such as over-collection of fuel and fodder, over-grazing, shifting agriculture, and regeneration of fodder grasses through annual burning—are well known. These ecologically unsound activities are not new; but in recent years they have caused an unprecedented amount of environmental damage and now threaten to virtually destroy the Himalaya's natural resources.' (Campbell 1979, cited in Messerschmidt 1987, p. 377).

that the condition of SNP forests has been misinterpreted. Evidence for a significant recent reduction in forest cover is absent. Yet researchers have been quite comfortable with the still-prevailing view that the Sherpa's first arrival coincided with—and probably began—a process of deforestation, and the Sherpa's cattle are uniformly targeted as agents of forest destruction.

Livestock

The Sherpas' herds of yak and other livestock enjoy pride of place in most explanations of the initial removal of forest and the subsequent suppression of regeneration. The first Sherpa warden of SNP, newly returned from New Zealand with a diploma in park management from Lincoln College, was explaining the Himalayan Trust's efforts to rid the park of goats—the quintessential destructive domestic beast—told us that he thinks there is something poisonous in goat saliva. The warden may have misinterpreted the mechanism, but it's likely he understood the essence of the message taught at Lincoln College. It's a common enough message in forestry schools and environmental studies programmes, among conservationists: livestock grazing and forests don't mix (Day 1930; Dambach 1944; Patric and Helvey 1986; de Witt 1989; Dennis in preparation).

That has been the message, certainly, in nearly all attempts to come to grips with the dynamic interaction of forests and Sherpas in SNP. In almost every account promoting SNP, in plans for management of the park, and in reports by trained and lay visitors alike who comment upon the status of forests, livestock rank high as culprits in the retreat and degradation of woodland (e.g. Naylor 1970; Blower 1971; Mather 1973; Mishra 1973; Lucas et al. 1974; Speechly 1976; Bjonness 1980; Garret 1981; Jeffries 1982; von Haimendorf 1984; Byers 1987c; Hardie et al. 1987; Miede 1987; Ledgard 1989).

The remaining forest . . . is fast disappearing and will have probably vanished altogether in a few years unless properly managed . . . The main problem . . . is that heavy grazing by yak and other livestock destroys all young tree growth through browsing and trampling and therefore prevents natural regeneration of the forest (Hardie et al. 1987).

Case study: Testing assumptions about grazing and the forest landscape

We were uneasy to lay responsibility of forest damage on Sherpa herds, in the absence of any confirming study, in light of the array of erroneous assumptions commonly made about ecological processes in the Himalaya, and in the face of conflicting preliminary work (Brower 1987). We sought to clarify the implications of livestock grazing for Khumbu's forest landscape, and set out to explore two hypotheses: (1) that forests are declining and (2) that the scrub vegetation that dominates most slopes near villages is degraded remnant forest. Evidence of declining forest would include lack of regeneration within stands, at canopy gaps, and at the edges of stands; regeneration within stands and at stand edges, and a

pyramidal age structure would refute this hypothesis. Scrub vegetation composed of a subset of forest under story species plus species with 'invader' biology would be expected in shrub-grassland produced from degraded forest; floristically rich and distinctive shrubland argues against such origins. Accordingly, we designed a small-scale, exploratory study of forest plots located above the confluence of the Bhote Kosi and Imja Khola, near the Sherpa settlements of Namche Bazar, Kunde, Khumjung, and Tashinga. We conducted the study in monsoon of 1990.

The location

The triangular 'plateau' defined by these joined rivers is the area of densest population and most concentrated land use within Khumbu. It is also the place subject to most extensive speculation about the role of human occupation in eliminating forest. The slopes around these south-facing settlements are typically identified as former forest degraded to scrub through some combination of Sherpa burning, grazing, and forest felling (Halkett 1981; Hardie et al. 1987). The area is underlain by migmatitic orthogneisses and the surface topography is the manifestation of pre-glacial v-shaped troughs and platforms overprinted by glaciation and subsequent mass wasting, and relief from valley bottom to peak ranges from 2000 to 4000 masl (Vuichard 1986). Monsoon delivers yearly rainfall between June and October, some rain falls in April and May as a result of convective heating in the plains, and winter storms, though sporadic, can produce substantial snowfalls. Specific weather data are scarce, and conditions vary widely across Khumbu, but a weather station maintained at Namche Bazar (3440 masl) reported a January mean of -0.4°C (the coldest month), a July mean of 12°C , and an average annual precipitation of 1048 mm with a range from 708 to 1710 mm (Joshi 1982).

The study area is subject to grazing by a total population of about 1200 animals, maintained by 300 households and a government yak-breeding facility. Traditionally, Sherpa cattle made use of ranges extending from below main settlements to the snowline above 6000 masl. Sherpas managed their animals in such a way as to distribute the impacts of grazing over space and time, using individually-owned huts and hay-fields as a base from which to graze successively higher pastures, and discouraged by such cultural mechanisms as the *di* from leaving livestock too long near settlements (Brower 1987; Sherpa 1999). Tourism's need for load-carrying packstock and competition for herder labour have undermined such traditional range-management mechanisms, and today livestock remain concentrated nearer the villages most of the year. Although the villagers of Kunde and Khumjung pride themselves on maintaining their *di*, Namche's livestock population has grown, and depends on our study area's grazing resources. Yak, 'hilly cattle,' and yak-cattle hybrids (female 'zum'; male 'zopkio') using the area are stabled at night in the villages and driven out each morning to forage for themselves. In winter, limited feeding of hay and household scraps may supplement the diet of particularly valuable animals, but most depend primarily on grazing and browsing. According to previous studies (Bjonness 1979; Bjonness 1980; Brower 1987) and our observations, grazing pressure in the vicinity of these villages varies from moderate to severe. Six of the seven sample sites (Namche North and Komuche) are subject to grazing year-round; the others—at Tashinga and Kunde—are

protected, at least in principle, by restrictions on grazing during part of the summer (Brower 1990). Each sample plot is well within the daily foraging of livestock maintained by local Sherpas. Pure cattle are a larger proportion of the stock having access to some sites (Namche North), crossbreeds dominate others (Komuche), and pure yak are a larger percentage of the total stock likely to be grazing those plots near Tashinga. These differences may be reflected in grazing effects, for the feeding behaviours and preferences of Sherpa cattle vary according to breed (Bonnemaire and Jest 1976; Brower 1996).³

Within this area we chose a dispersed set of sample sites in fir (*Abies spectabilis*) woodlands within a few minutes walk of settlements. Sites are similar in elevation but represent a range in both grazing use conditions and levels of stand closure. All but one of our study sites lie between 3500–3680 masl in three locations, representing different combinations of slope, aspect, and level of grazing use; we designate them Tashinga, Komuche, and Namche North. We chose an additional site within a stand above the village of Kunde that had been previously identified as manifesting stand decline.⁴

At these elevations within Khumbu, more southerly aspects support shrub/grassland vegetation dominated by low-growing rhododendron (*Rhododendron lepidotum*) and cotoneaster (*Cotoneaster microphyllus*). Tall shrub vegetation with birch (*Betula utilis*), fir, and tree rhododendron (*Rhododendron campylocarpum*, *R. campanulatum*) dominate the more northerly aspects. East and southeast aspects support fir forests of various densities mixed with shrub vegetation including tall species of *Rhododendron* and *Cotoneaster*, *Salix*, and *Rosa* and many species of the rhododendron–cotoneaster shrub/grassland assemblage. We make no statistical inferences regarding differences, similarities or trends among plots; rather we treat them as an aggregate of separate case studies.

Results

Our findings, summarised here, suggest that interplay of site factors shapes the present configuration of the forest/shrub landscapes of Sagarmatha National Park (SNP). Though each of the four study locations tells a somewhat different story, together the sites suggest that altitude, aspect, and slope steepness are the most important elements determining whether forest becomes established and subsequently thrives. Our study sites show that contemporary grazing has at most a limited effect on the regeneration of forest, significant—if at all—only when acting in conjunction with other type of stresses.

Tashinga

Tashinga is a *gunsu* (winter settlement) of small houses and associated fields, occupying an area of moderate slopes facing dominantly east-southeast. All four of these sites showed light

3. In addition to impacts of wandering livestock, sample sites are also subject to collection of forest litter and deadfall, occasional wood-cutting, and to browsing by musk deer and tahr (a wild goat).

4. Within these subjectively chosen sites, study plot locations were selected using randomly chosen co-ordinates for initial plot corner and compass direction of first plot boundary. In most cases, a paired plot was chosen in contrasting vegetation, adjacent to the forest plot but not near the vegetation boundary.

to moderate grazing; the only evidence of wood-cutting were a few cut stumps of small trees on forest sites. The two plots on east-southeast aspects support fir forest, the oldest trees established since the 1930s. Plot-1 trees are larger, the peak period of establishment was between 1960 and 1964, and it is still a fairly open stand (Table 1). Plot 2 is denser, its trees smaller and younger, with high densities of seedlings and saplings mostly established since 1970. Height of large saplings on both sites exceeds the rates on all other sites we examined. Saplings less than 3 m tall, about 5% of Plot 2, indicate damage from browsing, but leader growth is equal in both browsed and unbrowsed trees, suggesting minimum impact. These can be characterised as actively growing *Abies* stands, within which human activities are having small effect.

Tashinga's north-north-east aspect supports tree cover comparable to these sites, but one-third of the trees over 1 m tall are birch rather than fir. *Abies* seedlings and small saplings are fairly abundant, but growth apparently stagnates, for trees up to 60 years old have diameters less than 10 cm; the oldest fir tree on the plot was established in about 1926 but is only 17 cm diameter at breast height (DBH). The more mesic conditions of this site, as of all north-oriented slopes in this elevation zone, appear to favour birch. Such sites permit the establishment of fir seedlings but forestall their continued growth.

The Tashinga plot with the most southerly aspect is a forest-free zone on the south-southeast slope, and supports rhododendron-cotoneaster shrub/grassland vegetation; a thorough search revealed a small number of small juniper (*Juniperus recurva*) plants but no fir or birch.

Komuche

At Komuche we sampled one forest plot (Plot 5) and two shrub/grassland plots (Plots 6 and 7). Komuche lies about 1 km northeast of the village of Namche Bazar, 5 km south of the Tashinga site. The general aspect here is more southerly and the slope steeper than at Tashinga. The area shows high current grazing use (a majority of grass clumps had been grazed short) by livestock—particularly hybrids—musk deer, and an expanding herd of tahr. Grazing pressures are concentrated on reduced range resources in the area near Namche Bazar: approximately 35 of the national park's 45 hectares of fenced plantation (Ledgard and Baker 1990) are located here, the yak farm has claimed a substantial area of former hayfield and range, and accessible forage has been significantly reduced. Forest stands in this area occur in isolated positions above rocky outcrops or in ravines diagonal to the generally steep slope of the hillside. This is the setting for Plot 5, which has the same east-southeast aspect and approximate elevation as the fir forest plots at Tashinga. The oldest trees here were established in about 1945—more recently than those at Tashinga. Establishment has apparently been intermittent since, with clear peaks between 1960–65 and between 1970–75. Long-term growth rates are less than at other sites in this elevation zone, and there are few seedlings or small saplings; sapling growth is much slower than on the plot with similar canopy closure at Tashinga (Table 1). Although about 45% of the saplings and small trees show browsing damage, as at Tashinga, browsed saplings do not show a reduced growth rate relative to unbrowsed saplings. There was no evidence of

woodcutting—no surprise; perhaps, since the site is close to SNP headquarters and the patrolling park rangers are housed there. Conditions on this rocky, steep and exposed site appear more hostile for seedlings and less nurturing for growing fir than Tashinga's fir plots.

One shrub/grassland plot here is very like that at Tashinga: predominantly *Rhododendron lepidotum* and *Cotoneaster microphyllus* less than 0.5 m tall. The other occupies a more northerly aspect and more closely resembles the Tashinga fir/birch site, though with only a few birches, most with multiple stems less than 3 m tall, occur on the site. These show signs of having been repeatedly browsed, although there is little evidence of browsing on current growth. Willows apparently have not been browsed and neither willow nor birch appears to have been cut.

Namche North

The sites occupying the southwest-facing slope of the Bhote Kosi valley about 0.5 km northwest of Namche, contain more well-developed forest cover than the Tashinga and Komuche sites. The site nearer Namche (Plot 8) shows somewhat heavy grazing use, and the one farther on (Plot 9) shows light-moderate use. We saw crossbreeds at these sites but found no sign of musk deer or tahr.

Plot 8 had the largest and oldest trees of all the plots in this elevation zone—up to 77 rings and 36 cm DBH, implying trees established around 1914 (Table 1). This site showed a peak of establishment in 1956–58. Plot 9 had more complete canopy closure and more trees in larger size classes. Maximum age and size were, however, somewhat less than at Plot 8. The oldest tree on Plot 9 was established in about 1936 and measured 29 cm DBH. Long-term growth rates were high in terms of the sites considered here—similar to those at the Tashinga fir sites and considerably higher than at Komuche. Sapling growth, however, was quite slow. Both plots had low numbers of small saplings but very high numbers of seedlings. Low recruitment of seedlings into the sapling class and slow current sapling growth may be a response to shading by the fairly closed canopy of these sites.

A separate case: Kunde

We sampled a 10th plot on the hill above Kunde at 4020 masl on a southwest-facing slope (Table 1). This area is a gently sloping, smooth herbaceous sward, in contrast to the steep terraced topography of all other sites in the study. This site had the largest and oldest trees (up to 43 cm DBH, established as long ago as 1890) but the stand was very sparse with only 16 percent canopy closure (Table 1). There were few seedlings. Over half of the individuals in the small sapling class were dead, and there was abundant evidence of severe browsing damage. Sapling growth estimates have limited meaning since they are based only on the few live individuals in this size class, but are certainly very low. Long-term growth rates of the larger trees have also been very slow. In contrast to other sites, cut stumps were obvious. Most of these were less than 5 cm in diameter, but there were some stumps of larger trees and holes where large stumps had been removed in the vicinity of the plot. There was little shrub cover at this site, and species composition had little resemblance to other sites.

Table 1. Number of individual trees within size classes found in each of the sample sites.

		Number of individuals/1000 m ²						
		Tashinga	(Fir sites)	Tashinga (Birch)	Komuche	Namche	North Sites	Kunde
Age	Year established:							
	Since 1976	1829	14,865	403	94	12,338	7213	77
	1961-75	72	46	68	52	78	48	8
	1946-60	10	8	30	10	60	76	3
	1931-45	12	8	6	0	14	10	0
	Before 1931	0	0	3	0	6	0	8
Oldest tree		1935	1927	1941	1947	1915	1937	1891
Size	Seedlings	1742	14,488	225	33	12,288	7150	50 (+43 dead)
	Saplings (to 5 cm DBH)	115	410	254	100	95	88	28 (+60 dead)
	Small trees (to 20 cm)	60	18	30	20	100	75	8
	Large trees (>20 cm)	6	10	0	3	13	35	10
	Largest tree (cm DBH)	24	27	17	21	36	29	43

(Plots within sites are averaged)

Discussion

Kunde clearly shows evidence of forest decline: few seedlings, high mortality of saplings, and few trees in intermediate size and age classes. Low diameter growth rates over the lives of the few large trees show that conditions for growth at this site are poor even for individuals in size classes that are little affected by current browsing and trampling.

However, browsing and tree cutting have every manifestation of being major factors in mortality of small trees. Clearly, unless conditions improve for survival and growth of small trees, the large trees on this site are unlikely to be replaced and the stand will thin even further or disappear. In spite of apparently heavy grazing, vegetation cover at this site is complete and there is clearly no accelerated soil loss-taking place. This, together with observations by Byers (1986) at similar sites, suggests that it is unlikely that livestock impacts on soil productivity are a major factor in the decline of the forest at this site.

The under-story community here, though equally diverse, shares relatively few species with any of the sites at lower elevations. All of the shrub species that form major components in both the lower elevation forest understory and shrub/grassland sites are absent here, as are all the grasses and herbs that are major vegetation components on those sites. Clearly, many plant species typical of fir forests and associated communities reach their environmental limits below the elevation of this site, and this site is clearly at the uppermost limit for fir. Timberlines fluctuate, and the older trees on this site may have been established under environmental conditions more favourable than those that exist today. Damage from grazing and woodcutting may not be the only limiting factor operating here.

Fir forests at Tashinga and Namche North, in contrast, do not have characteristics we expect in declining stands. On the contrary, what we see at these sites is consistent with

young stands at various stages of filling in. While at Kunde cut stumps and holes where stumps have been dug out were obvious, at these sites we did not find any evidence to suggest that tree cutting in recent years has reduced the number of large trees. Rather, the oldest trees here appear to have been pioneers on a previously unforested site. Composition and floristics of the under-story vegetation support the interpretation of these as sites that were shrub/grassland with scattered trees rather than more dense forest vegetation in the recent past. On all these sites, the understories bear strong resemblance to nearby shrub/grassland. The herbaceous understory differs from the shrub/grassland by absence of individual common species, a different set in each case, rather than by presence or absence of a common set of species or, alternatively, presence of species characteristic of more fully developed fir forests elsewhere in these valleys (see Byers 1986 for lists of these species). The under-story shrub component does show signs of acquiring a distinctive set of species not characteristic of shrub/grassland—the tall shrub/small tree species of *Rhododendron*, *Salix*, *Cotoneaster* and *Rosa*. At present, these species are minor components of cover (less than 5%) on these sites.

The Komuche site presents a somewhat less certain picture. Looking only at trees over 1 meter tall, we see a young, expanding stand, the pioneers of which became established in the late 1940's. However, populations of seedlings and small saplings are relatively small. Sapling numbers and growth rates resemble the rates in closed canopy at Namche North rather than the rapid rates of open stands at Tashinga. Growth rate of large trees is lower than at either Tashinga or Namche North. Direct or indirect effects of livestock and tahr, both of which use this area heavily, could well be major factors in low seedling numbers. However, contrary to the Kunde case, it is not clear that browsing is directly causing either reduced growth or mortality for saplings.

As with Tashinga and Namche North, understory characteristics support an interpretation of this as a young stand, not a depleted remnant of a formerly more dense forest. Intermittent establishment appears to have been the pattern over the history of the existing stand. Animal impacts may interact with environmental factors to limit regeneration, except in years with favourable combinations of both the animal and environment. It is certainly possible that recent changes in livestock use in this area could reduce the frequency at which those favourable circumstances occur. Trees now in the sapling stage can reasonably be expected to survive and produce some filling in of the stand, but it is not clear if further stand development is likely to occur. Site 3, the north-facing stand near Tashinga, shows that poor conditions for growth, not grazing, are probably the limiting factor in expansion of fir forest onto northerly aspects. Although the mesic environment of these sites is apparently favourable for seedling establishment and initial growth, it is clearly not favourable for continued growth. It is highly unlikely that livestock trampling or browsing would be limiting growth in this size class without also affecting smaller trees. The shift in understory species composition between these sites and adjacent more southerly aspects shows that other species also reach environmental limits on these shady slopes. It is striking that no fir seedlings were found in shrub/grassland plots. Plots had vegetation similar in structure and composition to the fir stand understories and there were no apparent differences in level of livestock use, density or condition of trails and terracettes, or level of herbage removal between adjacent scrub/grassland and forested sites.

We do not have specific information on seedling physiology at such sites for *Abies spectabilis*, but we do for a number of other *Abies* species. All the North American *Abies* species are shade tolerant and sensitive to heat and desiccation at seedling stage. For these *Abies* species, seedling survival is greatly enhanced by shading, although established trees tolerate and grow more rapidly in full sun (Burns and Honkala 1990). If *Abies spectabilis* is similar, high seedling mortality in full sunlight may largely account for the scarcity of seedlings on the scrub/grassland sites. This would fit with several other patterns we have observed: the delay between establishment of the first cohort on a site and subsequent population expansion; abundance of seedlings on the Tashinga birch/fir site; the Namche North sites where conditions for subsequent growth are poor at the present time; and the scarcity of seedlings on the steep, exposed Komuche site.

Given the evidence for stand dynamics at these sites, which among them represent a range in altitude, aspect, slope and livestock-use variables, we suggest the following process:

1. Establishment of fir seedlings in shrub/grassland is a rare event because seedlings are vulnerable to desiccation. Establishment events are likely to be more frequent on shadier aspects, on sites protected from wind, and near seed sources.
2. Past the critical establishment phase, shrub grassland sites are suitable for fir growth.
3. Because of the relative unpalatability of fir and its rapid ability to replace damaged leaders, moderate browsing by livestock and other herbivores does not result in major foliage losses or retard growth of trees that are otherwise healthy.⁵
4. Once pioneer trees grow big enough to produce a shaded, protected area beneath, seedling establishment increases rapidly.

Closing remarks

Our results show that concern about livestock impacts on fir regeneration in Khumbu is justified in some situations, but on the whole fir forests in the Namche–Kunde–Khumjung region are expanding and livestock grazing has little indirect adverse effect on tree regeneration and growth. Regeneration problems do occur where environmental limits to growth interact with browsing pressure near timberlines. However, we found that there was ample regeneration on sites representing a range of grazing conditions, from relatively moderate, controlled use near Tashinga to fairly heavy and less controlled use within half a kilometre of Namche Bazar. Observations of vigorous fir regeneration on very heavily grazed sites at 3800 masl just south of Kunde (in an area of much recent tree cutting) further support our conclusion that grazing alone would rarely prevent fir regeneration. Our findings on age structure, vegetation composition, and floristic characteristics all support this conclusion. We see the relationships between human impacts and forest stand dynamics hinging on the particular biology of *Abies spectabilis* in this location, especially its sensitivity to desiccation at the seedling stage, its relative unpalatability to large herbivores,

5. This may not be true under conditions of heavy browsing on plantation-grown *Abies* by native browsers such as tahr, as evidenced by substantial reduction in fir shoots relative to pine in plantations above Namche recorded this summer.

and its tolerance of moderate browsing when otherwise healthy. We would not necessarily expect to see similar relationships with species that differ from *Abies spectabilis* in these characteristics.

Our conclusions agree with those drawn by Houston (1982) and Byers (1987a, b, c): forest cover is increasing in the 3400–3800 masl zone in the Namche triangle. Sparse stands and lone trees in this zone are pioneers, not remnants of formerly more dense forests, as researchers in the field speculated (Hardie 1974; Speechly 1976; Bjonness 1979; Bjonness 1980; Halkett 1981; Bjonness 1983; Miede 1987).

We would like to make a further point regarding the shrub/grassland vegetation, characterised as ‘degraded’ by these authors. Our results show that *Rhododendron lepidotum*-*Cotoneaster microphyllus* shrub/grassland is a rich and diverse plant community in its own right. It is in no way a collection of forest species that have clung to life in spite of overstory removal and grazing, nor is it composed of pioneering species. It is clear that boundaries between shrub/grassland and forest have shifted over time on the sunny slopes of Khumbu. In the long term, each has repeatedly been ‘secondary’ to the other. The fact that human activities have probably had a major role in some of these shifts does not inherently make the community type favoured by human activity ‘degraded’. We can in fact recognise degraded conditions in either shrub/grassland or forest and we can find examples of both in Khumbu (the steep eroding trails and heavily trampled areas above Namche, for example). We recognise degraded conditions as ones where accelerated soil loss is occurring, or where species characteristic of the community are missing. In contrast, intact shrub/grasslands like the ones we examined in this study and observed elsewhere in Khumbu are not undergoing soil loss and provide habitats for a wide range of native species that do not occur in forests. Attempts to ‘restore’ intact shrub/grasslands to forest cover are counterproductive to maintaining the diversity of habitats of Khumbu and the full array of native biota these habitats support.

Implications for conservation

Our study suggests that ecology, to some extent, is in the eye of the beholder. Foresters, park planners and others convinced of the dangers of Himalayan deforestation, and unkindly inclined toward livestock, saw decline in the patterning of Khumbu forests, and agents of degradation in Sherpa herds. They somehow overlooked what would seem to be clear evidence of forest vitality (distracted, perhaps, by abundant evidence, such as that provided by ubiquitous stock-terrecettes, that in this landscape livestock have clearly been agents of other landscape change).

More partial to yak, leery of conventional explanations for ecological processes in the Himalaya, and with experience of unexamined prejudices against forest grazing, ours was a different perspective: we set our questions to test it, and our study offers a different result. It is, clearly, an exploratory study, and raises no end of further questions about environmental processes (e.g. what conditions and processes impede stand establishment? What factors explain the varying dates for the apparent pioneering of the stands we sampled? What is the role of natural and human-initiated fire in this area?). Cultural practices (e.g. Do Sherpa

livestock management practices influence the degree of grazing impact? How closely do contemporary grazing patterns reflect past practices? How do long term residents account for the patterns of forest establishment and maintenance that we observe?). And park policy objectives (e.g. is the vision of a forested Khumbu drawn from nature or from outsiders' expectations? Is plantation forestry appropriate given successful natural regeneration? Do we know enough to meddle with the environment and local culture? How can ecological understanding be separated from prejudicial training and values?). We await with interest the results of future work on some of these and other questions, and brace ourselves for the critique we hope will follow on our own attempt to make sense of the landscape of Khumbu. The outcome we would hope for is a conservation strategy for SNP that reflects a thorough and thoroughly neutral understanding of both ecological processes and the changing role of local people through time, one that recognises the mutability of scientific explanations and the legitimacy of local needs and values. Within the incredibly complex geopolitical-economic framework within which decisions about SNP and the world's other protected areas are made, let science play a central role—but always in the awareness of its limits.

Sagarmatha, of course, is not unique in requiring understanding of both natural and cultural processes as the foundation for conservation planning and management. The landscape valued here, a high-altitude, peopled foreground to the world's biggest mountains, has its own distinctive history, and reflects responses to a very particular set of conditions. The inherent instability of high mountains presents one set: an ever-changing interaction of climate, slopes, and biota. People and their yak introduce another set of influences on landscape processes that change along with the lifeways of Khumbu's residents, and interventions of Sagarmatha's managers. The processes and patterns that characterise this particular Himalayan landscape are not, after all, part of some regional scheme. Yet for all its distinctiveness, Sagarmatha/Khumbu's forest landscape is a product of the same broad dynamics of establishment and decline that shape landscapes everywhere. Understanding the particular expression of those dynamics, here as anywhere, requires a suspension of presumptions, a careful analysis of a complex spectrum of factors, and a willingness to re-examine interpretations of landscape-making derived from inadequate understanding of dynamism, complexity, and untested assumptions.

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Integrated ecological studies of pasture problems in the Tibetan Autonomous Region, P.R. China

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Summary

This paper presents a preliminary survey of high altitude pastureland in central and southern Tibet, comprising an outline of the methodological approach adopted and a description of the main findings. The extent, degree and age of pasture degradation are discussed, and of the many causes of recent pasture problems that are interrelated in a complex way. Particular attention is given to two factors: the cutting of peat and turf and to the alleged pika problem.

Keywords: Pasture degradation, pasture ecology, Tibet

Introduction

This paper presents the results of observations and discussions carried out in 1998 during the course of feasibility studies concerning the implementation of development projects in areas of southern and central Tibet. Some problems related to Tibetan pastures such as pasture degradation, pika calamities and snow disasters were encountered. To determine which technical measures could help solve these problems, a superficial survey of the rangeland areas passed was made, applying methods we had developed during previous ecological research in areas of the Himalayas outside of China (Holzner and Kriechbaum 1998). Anthropological enquiries, particularly in the Porong area of southern Tibet, were also carried out together with the Tibetan Academy of Social Sciences and a project investigating high altitude pasture ecosystems in the Austrian Alps, which combined ecological, economic and other human science data. An important observation that may be made here is that the problems encountered in the European Alps and the Himalayas and Tibet are similar; they are general problems of human economy and society in areas marginal to agriculture. In other words, the problems of high altitude rangelands are international problems.

In agronomy and other environmental sciences, we are faced with an increasing amount of problems, in spite of the fact that research is proliferating within these fields. Scientists are often called in to solve these problems, but the results of this approach are not

convincing. In this paper, we address the questions: Can the usual scientific approach solve the problems of high altitude pasturelands, and what approach has chance of success?

What is HAPIE?

High Altitude Pasture Integrative Ecology (HAPIE) tries to integrate the methods and results of the natural sciences such as biology and ecology with those of the human sciences such as anthropology, sociology and economics. Such an approach is absolutely necessary for investigations aimed at the solution of pasture problems. Pastures are areas used for agricultural production, bearing a biocoenosis of plants, wild and domestic animals and humans. Nomads, herdsman and farmers are members of the pasture ecosystem, as are their yak and sheep, and the grasses and birds. This is a natural matter of fact, and thus it seems wise to act accordingly. It does not make any sense to deal with pasture areas from an ecological point of view alone, nor can we concern ourselves only with the economics of pasture agronomy. Instead, an integrated approach, which addresses all the pieces of the puzzle together, is the only one where the results of applied science can be put to practical use.

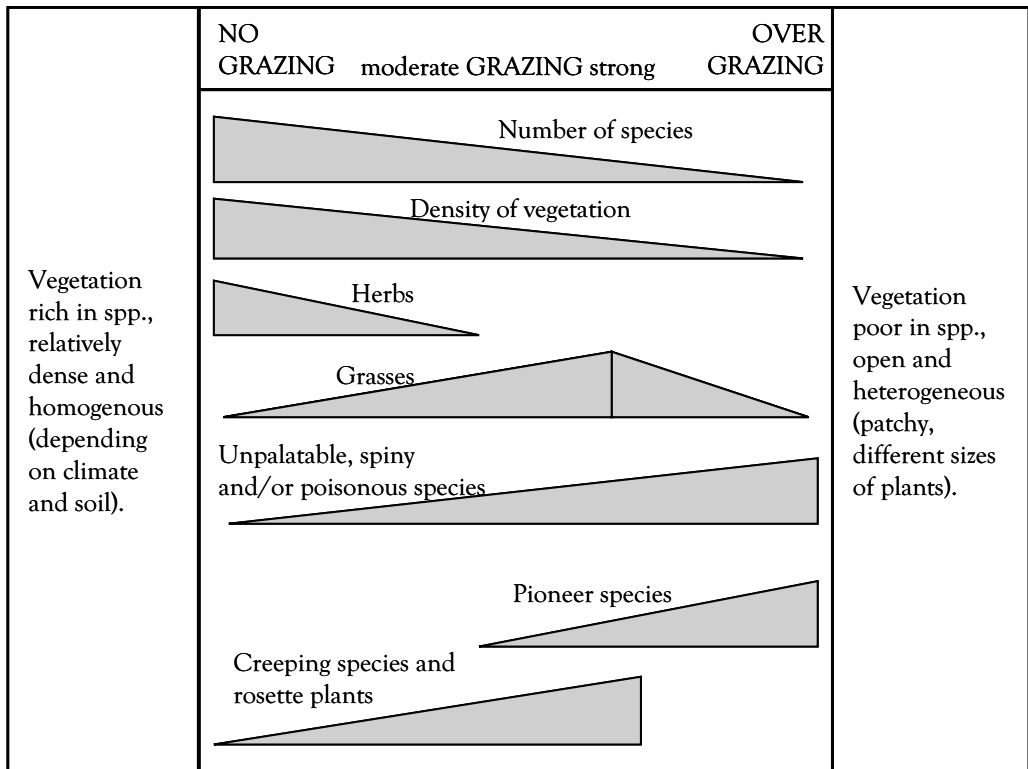
The goals of HAPIE are not set by science but by the concrete problems of life. HAPIE attempts to translate the knowledge of modern science and technology into practical measures with the goal of achieving optimal and sustainable use of high altitude pastures for the welfare of human society. Thus, it is necessary to view the pastoral system not only from outside as scientists do, i.e. a scholarly approach, but also from the inside, with the eyes of a herder or a yak. This approach has several advantages. For one, it can help to avoid academically generated solutions, which often hamper progress, waste time and energy, and do not particularly produce feasible results that are transferable to the people for which the study has been performed. On the other hand, a herder's eye-view can help define goals and terms more easily and more accurately. For example, 'overgrazing' simply means a mode of utilisation that prevents vegetation from recovering in the periods between grazing, with the result that the same vegetative yield cannot be achieved in the following year, provided weather conditions are comparable. Constant overgrazing causes 'degradation', a process that produces a gradual, irreversible change in pasture quality and quantity. 'Irreversible' does not mean that this process cannot be reversed, a condition that is very difficult to judge, but that a return to the former state would take at least several years or decades. This is unacceptable, or at least represents a substantial loss, from a herder's point of view because it means that the pasture should not be used at all for at least the duration of the recovery period. In the long run, degradation leads to a pastoral 'desert', a land practically devoid of palatable plants. From this point of view, 'desertification' does not mean an area free of all vegetation, but only free of usable forage.

Methodology

HAPIE requires complex thinking and a general methodology that is able to interlink not only the results of different fields of science, but also to combine 'hard' scientific data with

so-called ‘soft’ information, like ‘herders’ opinions or traditional knowledge. Thus, the results are products of science and technology on the one hand, and a different kind of approach to nature, which relies on direct experience derived from observation and mixed with ‘inherited’ or traditional knowledge.¹ Both approaches are considered equal. The methods themselves, however, must be simple. They must be specially designed for the particular purposes of the project and the ways the results have been drawn must be obvious and clear. Besides that, applied research, which delivers truly applicable results, must be fast and inexpensive, with the results presented publicly in a way that everybody can understand.

For the purpose of this study, a set of simple and complex indicators was employed using specific vegetation parameters, like species numbers, relative numbers of ‘pasture weeds’ to palatable plants, relation between herbs and grasses, and the percentage of pioneer species (Figure 1). These indicators are easily recognised, and can be used also by non-specialists (Holzner and Kriechbaum 2000). The degree of precision that can be achieved with them is sufficient for the purpose of this study. With these indicators, the condition of a pasture can be roughly judged, in terms of whether it is in an optimal state or a state of degradation, and if the latter, whether this degradation is of ancient (centuries-old) or recent (decades-old) origin.



Adapted from Holzner and Kriechbaum (1998).

Figure 1. Development of some vegetation indicators along a gradient of grazing intensity.

1. This paper actually has many more authors than the ‘western’ scientists (ecologist, agronomist and anthropologists) listed above. Besides officials (see acknowledgements), several Tibetan nomads have generously shared their wisdom with us.

Additionally, the most widespread pasture types were classified, mainly according to the dominant species or most important forage plants. These botanically-defined types match with the pasture classification of the nomads, and it was noted that results achieved from the combination of the two different sciences were particularly useful.² For each of these pasture types, the agricultural value and the form and degree of degradation was estimated by using the indicators mentioned above (Table 1).

Table 1. Common pasture types of southern and central Tibet.

Pasture type	Dominant plants	Tibetan name ¹	Class	P	Q
Pygmy Kobresia turf	<i>Kobresia pygmaea</i>	pangtsa	OP ADP 1	2	5
Feather grass steppe	a) <i>Stipa</i> spp. and other (small) tussock grasses b) <i>Stipa purpurea</i> , <i>Oxytropis chiliophylla</i>	chema sagshi, nekarma	OP	1-3	4
Jag pasture	<i>Trikeria hookeri</i>	jag	OP	2	4-5
Turquoise sedge pasture	<i>Carex moorcroftii</i>	longma	OP	1-3	3
Giant Kobresia bog	<i>Kobresia schoenoides</i>	nama	OP	5	4
Dwarf shrub pasture	<i>Dasiphora</i> , <i>Juniperus</i> , <i>Myricaria</i> , <i>Hippophae</i>		OP	1-3	2
Micro-sedge pasture	<i>Carex microglochin</i>		RDP 1-2	2	5
Bulb Kobresia pasture	<i>Kobresia royleana</i>		RDP 3	2	4
Worm wood steppe	a) <i>Artemisia</i> spp. b) <i>Artemisia xigazeensis</i>	yog mo löma	ADP 4 OP	2-3 2-3	4 5
Rampa steppe	<i>Pennisetum flaccidum</i>	rampa	ADP 3	3	4
Semi-desert pasture	<i>Astragalus</i> spp., <i>Stellera chamaejasme</i> , <i>Incarvillea</i> , <i>Cryptothladia</i> , <i>Tanacetum</i> , <i>Iris</i>		RDP 6 ADP 4-5	2-1	1-3
High altitude pasture	<i>Kobresia</i> sp., <i>Stipa purpurea</i>		OP	2	4
High altitude semi-desert	<i>Androsace</i> sp.		ADP 4-5	1	2
Edelweiss semi-desert	<i>Leontopodium nanum</i>		ADP 5	1	1
Duk tsa pasture	a) <i>Oxytropis tatarica</i> b) <i>Thermopsis lanceolata</i> c) <i>Astragalus</i> sp.	duk tsema shendzima	RDP5	2-3	1
Stinging nettle pasture	<i>Urtica hyperborea</i>		RDP5	2	2

OP = optimal pasture; ADP = ancient degradation, RDP = recent degradation, the numbers indicate the intensity of degradation; P = productivity; Q = quality. The numbers are the result of relative estimates between the two extremes, the Giant Kobresia pasture (5) and the Edelweiss semi-desert (1).

1. Tibetan plant names given by local people are rendered in phonetic approximation.

Source: revised from Holzner and Kriechbaum (2000).

2. The nomads are excellent botanists, though not in the usual biological science sense. They have their own science, which is as valid as ours and sometimes more useful, depending on the particular purpose. Results received from the combination of the two different sciences are particularly useful.

Results

Summarising the experience of our studies, pasture conditions prevailing in southern and central Tibet are estimated as follows: About 30% of the pastures investigated were in optimal condition, about 20% showed signs of recent but complete devastation and about 20% were heavily degraded, the causes dating back centuries. The remaining 30% fell somewhere between the optimal state and heavy overgrazing, though it was difficult to judge whether that degradation was of ancient or recent origin.

The fact that large areas³ of Tibetan pastureland has been kept in optimal condition for centuries—optimal from an economic as well as an ecological point of view—can be taken as evidence that at least some of the Tibetan pastoral systems must have been sustainable.

Causes of recent pasture problems

External factors—climatic

The causes of recent pasture problems are not yet completely understood, but in any case they are very complex, involving both natural and human factors, e.g. climatic and pastoral system changes. In several areas of Tibet it is quite obvious that during the last few years, wells and rivers have been drying up with increasing frequency. Whether this is an independent tendency or partially caused by the loss of vegetation cover due to local overgrazing and cutting of the forests, remains an open question. A major cause of the so-called snow disasters seems to be a shifting of summer precipitation, when the plants can make use of the moisture, to winter, when it is of less use to the plants but makes access to them difficult for livestock. It is still unclear whether this is just a transient climatic aberrance or a general trend that will continue into the future.

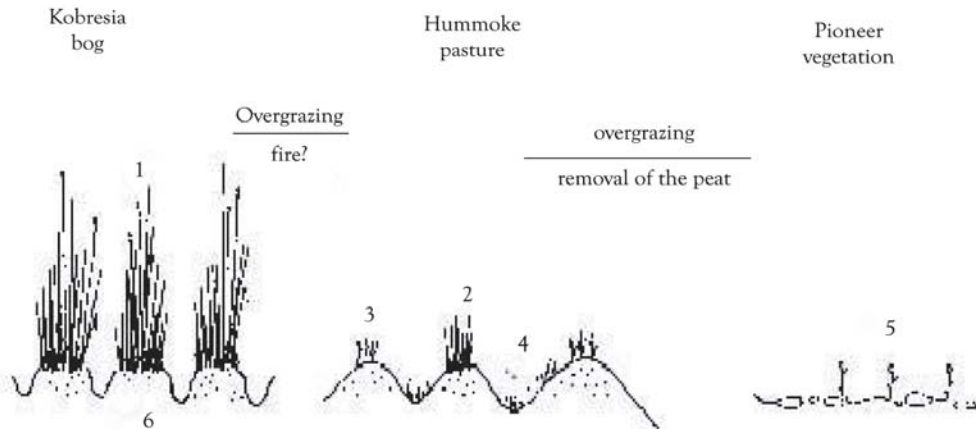
Internal factors—anthropogenic

From the many and interrelated anthropogenic (human-made) factors that are responsible for pasture degradation, we shall consider only two: the cutting of peat and turf, and the pika 'problem'.

The cutting of peat and turf: There are two main types of vegetation in Tibet that accumulate peat: Giant Kobresia (*Kobresia schoenoides*) bog and pygmy Kobresia (*K. pygmaea*) turf. Giant Kobresia makes for good pastures that are very conspicuous in the landscape due to their dark green colour. The intermediate states, in which, mainly because of overgrazing, the tussocks are partly decomposing and slowly and gradually becoming flatter and flatter, are also widespread, characteristic landscape elements. The decomposing tussocks are often covered by dense micro-sedges (*Carex microglochin*) vegetation, which also makes good pastureland but is much less productive than the Giant Kobresia bog. The thousands of

3. Sustainable use of the pastures did not prevail in the whole of Tibet. In quite large areas we found signs of severe ancient degradation and desertification of the pastures.

tiny, spring-green hills with their soft outline set off against the desert-like mountain slopes by the rays of the low-lying sun are a motif often depicted in photographs. We call this type of pasture ‘hummock pastures’ (Figure 2).



Adapted from Holzner and Kriechbaum (1998).

1. *Kobresia schoenoides* 2. *K. schoenoides* remains 3. *Kobresia pygmaea* 4. *Carex microglochis* 5. pioneers 6. peat
Figure 2. Degradation cycle of a giant *Kobresia* bog to desert by overgrazing and peat removal.

Huge areas at high altitudes (or northern slopes in lower areas) can be covered by a turf of *Kobresia pygmaea*, which makes particularly good yak grazing land. The peat-like underground formed by the living subterranean parts of the plants, as well as by the partly decomposed ones, is hard but springy and extremely dense and therefore resistant against trampling by herbivores, even by the large and heavy yak.

The cutting of bricks out of these two types of turf, mainly for the purpose of making walls or wind shelters, is an old custom that is being practised increasingly nowadays. The reason is increasing demand, in part because peat bricks are even used to improve road verges and to build houses, and especially because nowadays trucks can easily transport large amounts of turfs away from the nomadic areas.

The cutting of turf or peat means the removal of the vegetation together with all or most of the soil. During subsequent years, the scarce soil remnants are removed by wind and water. An intermediate, semi-desert state is produced featuring characteristic vegetation that cannot be called ‘pasture’ any more because the vegetation cover and its productivity are extremely low. Recovery of the former pasture is very unlikely if Tibet’s severe climatic conditions are considered. In any case, it takes such a long time that the degradation can be called irreversible from a nomads’ point of view. The final result is desert, stone or gravel pavement, with very scarce vegetation nourished by the remnants of soil, which escaped erosion because it was protected under stones.

It is very difficult to assess the extent of this process in the past. However, it could be that at least some of the desert-like areas of Tibet are the result of such activity, which might have

taken place in regions with a dense human population or located close to towns, where it was profitable to sell the peat.

Nowadays, turf cutting is widespread (though we were told that it has been prohibited since 1988). As the removal of turf or peat means the removal of the pastureland forever, this practice seems to be the most severe of the complex impacts destroying the pastures. Actually, it is difficult to say that the cutting induces pasture problems, because it simply removes the pastureland and therefore also the necessity to look for proper pasture management possibilities. However, far worse than having pasture problems to deal with is the notion of having no pastures at all. Thus, peat cutting is not only a problem in terms of pasture use in Tibet, it is a general ecological catastrophe for the whole country because soil and vegetation are simply sold and lost forever. Whereas the peat sponge retains moisture in the area, the water from rain and melting snow now runs off directly from the land into the rivers instead of being gradually emitted into the air. A regeneration of completely destroyed vegetation is unthinkable or only conceivable within a time span of hundreds or thousands of years.

The pika 'problem': Pikas (*Ochotona curzoniae*), called *abra* in Tibet, are relatives of hares and rabbits but are much smaller, about 20 cm long, and have shorter ears. In some pasture areas they live in astonishing numbers and are consequently considered major pests. The notion that pikas are a major cause of the poor condition of some pastures seems logical, because it is the usual reaction of humans to look for external enemies or pests as the source of our problems. From the viewpoint of HAPIE, this widespread opinion is not only questionable but also dangerous: It is easy to find a scapegoat to blame problems on, but it distracts us from looking for the true causes of those problems. In the case of pikas, huge extermination programmes have been organised instead of conducting investigations into the basic causes of pasture degradation.

Despite the extent of pika control programmes, the condition of the Tibetan grasslands apparently could not be improved. It is impossible to kill all the pikas, as others will soon fill the gaps because low population densities promote their reproduction rate. Moreover, the extermination of pikas in an area creates severe food problems for their predators, such as foxes, weasels and birds of prey. This reduces the predators' reproduction rate and ultimately leads to their starvation or exodus. Consequently, killing pikas also means reducing the numbers of their natural enemies, who assist the pastoralists in pika control. Thus, this kind of effort to control the pika population cannot have the desired results, but will exacerbate the problem still further.

According to our observations in many pika-infested areas, as well as detailed studies in certain localities, pikas take advantage of previous pasture destruction. From both an ecological and an economic point of view, the best method for addressing the pika 'problem' is to find the prior causes of pasture deterioration since it is these causes, which ultimately underlie the pika population explosion. Viewed from this angle, improving pastures will automatically reduce the number of pikas that live on them. Investigations conducted by Chinese scientists led to the same conclusion: When the amount of vegetation cover and the height of vegetation are reduced by overgrazing, pikas may be found in higher densities and consequently are in a position to do greater harm to the pasture environment (Shi 1983, and Zhong et al. 1985, both cited in Smith et al. 1990).

Additionally, efforts should be made to boost the population of pika predators. Miller et al. (1992) mention that the prior reduction or elimination of predators by hunting or poisoning appears to have been accompanied by an increase in pika populations. Laws protecting them may not be enough. Advertising campaigns promoting them as helpers in efforts to improve pastures could serve the purpose better.

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Development dynamics of fragile pastoral systems of the south-eastern Tibetan Plateau

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Summary

This study was conducted in Deqin County of north-western Yunnan, an important yak-raising area in China, and focused on the recent development of pastoral production systems. The status of rangeland resources and forage productivity, yak grazing patterns, changes in management systems, livestock structure and pastoral output in recent years were examined. Recommendations based on identified socio-economic and ecological features are provided in this paper in order to promote the sustainable development of pastoral production.

Keywords: Pastoral production, rangeland ecosystem, Tibetan Plateau, yak

Introduction

Rangeland ecosystems on the Plateau-Tibetan are some of the most fragile and dynamic ecosystems in the world. They comprise about 38% (149.3 million km²) of the grasslands in China (Zhou et al. 1995; Wu 1997a), and have been neglected by the rest of the world because of their inaccessibility and remoteness (Miller and Craig 1997). At present, maintaining rangeland productivity and biodiversity, increasing livestock offtake to meet growing demands and improving the living standards of local people are challenging tasks in this high-altitude region.

Yak is native to the high altitude areas of the Qinghai-Tibetan Plateau and the surrounding regions and is the only bovidae species that can fully utilise alpine rangeland resources (Wu 1997b; Wu 1998). The sustainable development of yak husbandry therefore becomes the fundamental guarantee for socio-economic development on the plateau. In addition, the unique pastoral cultures of the Tibetan and other indigenous ethnic groups of the plateau, sustained by extensive yak herds and the high-frigid rangeland ecosystems, are worthy of conservation. Understanding the complexity and mutual interaction of these pastoral production systems are prerequisites for promoting sustainable socio-economic and ecological development in this region. In the last few decades, unfortunately, many efforts have only contributed to rangeland revegetation and yak improvement, most of which stand in an isolated position and neglect the mutual action of whole system. Long neglect has negatively impacted traditional pastoral systems as well as rangeland ecosystems and enhanced by inaccessibility and poverty in a rapidly changing global economy.

The lack of concern for pastoral regions has led to a general downward spiral in the productivity, biodiversity as well as increased marginalisation of herders. This has limited options for the proper management and sustainable development of rangelands. Miller (1997, 1998) proposed that improving knowledge of range ecosystem processes, better understanding of pastoral production systems and more thorough analyses of the constraints and opportunities for improving the management of grazing lands will surely contribute to design more effective pastoral policies and rangeland development strategies. Rangeland management and sustainable pastoral development in the world's highest and largest mountain ecosystem should be of high concern in the world's economic development. The present paper is to examine the existing relationship among livestock, human demands, and rangeland ecosystems and to understand the recent development of the pastoral production systems in Deqin County of north-western Yunnan Province.

Materials and methods

Case study area

Located in the southern part of the Tibetan Plateau and on the north-eastern fringe of the Himalayan region, Deqin County is characterised not only by extremes in topography, but also by its environmental fragility and richness in both biological and cultural diversities. With the longitude from 98°35'6" to 99°32'2" and the latitude from 27°33'4" to 29°15'2", the county has a total area of 7596 km². The Jinsha River (upper Yangtze) and Langcangjiang River (Mekong) drainage cross the whole territory of the county from north to south, forming many deep-incised valleys. Ranging from 1800 metres above sea level (masl) to 6740 masl, mountain forests, subalpine forests and alpine meadow occur along the vertical gradient and some secondary communities dot the landscape. According to the land survey in 1996, the area of forests in Deqin is 2373.5 km², making up 31.2% of the total land surface, and the area of pastoral lands (including grasslands and scrubs) is 2508.7 km², amounting to 33% of the total land area. Agriculture, including cultivation and animal husbandry, is the main source for livelihood and income of both local people and government in this county. According to the statistics in 1994, the gross agriculture output value, including animal husbandry, comprised nearly 64.3% of the county, or 52 million RMB Yuan (US\$ 1 = 8.2 Yuan). In Deqin, yak husbandry has played an indispensable role in both subsistence and socio-economic development. Yak and yak-cattle hybrids are the most important grazing animals not only to provide milk products, meat, hair, and hides to local Tibetan households, but also to generate income and benefits to the mountain societies as a whole.

Data collection methods

This study surveyed the change of rangeland resources, grazing livestock, particularly yak and yak-hybrids, pastoral output, and management systems during fieldwork. Local herders and officials were interviewed in order to learn the traditional pastoral systems and

development processes. Some unpublished documents such as the Rangeland Map of Deqin County (1/100,000) were the partial results of the field investigations in 1985 organised by Deqin Bureau of Agriculture and Animal Husbandry. Community plot method was employed to investigate the rangeland types, forage plants, and edible aboveground biomass (Chapman 1976). The sampling area for every plot was 9 or 25 m². In 1998 and 1999, we reinvestigated the rangelands based upon the indications of the rangeland map in order to estimate any changes in rangeland resources. Over 30 plots were established. In order to estimate the total annual biomass production of each rangeland types, the biomasses production in different seasons were examined and monthly increment indices were determined. The method was firstly to monitor increment change in pasture with months on fixed plots and then identify average increment percentage for every month in per unit area. We found that the biggest monthly increment occurred in September, so we considered the increment index as 100% in September and increment indices in other months were accounted based on the ratio with the most monthly increment. Accordingly, indices 0.63, 0.83, 0.89, 0.92, 1.00, 0.45 and 0.40 were assigned to months from April to October, respectively. The annual aboveground biomass production in unit area of each rangeland type was measured by the biomass measured in the investigation month plus the rest adjusted by the monthly increment index. So the annual aboveground biomass production in unit area plus the area of the types used in the paper computed the total annual edible biomass of each pasture type. Deqin Bureau of Agriculture and Animal Husbandry provided data on change in livestock number, offtake and meat output.

Results

Change in grazing resources

In Deqin County the area of open pasturelands changed from 178,280 km² in 1986 to 205,942 km² in 1999, an estimated 15% increase. The major expansion of grazing lands has mainly occurred in the subalpine belt (Table 1). In Deqin, as well as in many other counties of the eastern Tibetan Plateau, the expansion of farming fields and commercial loggings have resulted in a decline in forest cover and the invasion of subalpine meadow or scrub (Wu and Liu 1998). The decrease in total annual edible biomass production is estimated to be 1.7%, from 517,582 tonnes in 1986 to 508,805 tonnes in 1999. A striking feature is that the biomass of alpine meadow and alpine scrub-meadow has declined, but the biomass of subalpine grazing lands (pasture among forests, thinning woodland-pasture and subalpine scrubs) has increased due to the expansion of pasture area.

Change in composition of grazing livestock populations

In Deqin County the total heads of domesticated animals increased by 8.5% from 1986 to 1998 (Table 2). It should be noted that the population of yak/cattle has increased by 17%,

but the population of goat/sheep declined by 29%. This trend has also been found in other Tibetan pastoral regions such as in Hongyuan County of Sichuan Province, which occurred after the implementation of the 'Household Responsibility System' in the 1980s (Wu 1999). Another apparent change is the dynamics of the horse population, which has increased over 124%. This is in contrast to other Tibetan pastoral areas where horse numbers have declined in the last decade owing to restrictions by local governments (Wu 1997b). The increase in Deqin may be attributed to the boom of tourism in the last decade, because horses and mules provide an indispensable means of transportation to mountaineers, trekkers and explorers. Because of the limited carrying capacity of the area, the increase of horse and mule population may directly affect the development of cattle/yak and goat/sheep husbandry.

Table 1. Change of pasture area and total annual biomass production in Deqin County.

Rangeland types	Pasture area (hectare)			Total annual edible biomass (tonnes)		
	1986	1999	Change	1986	1999	Change
Alpine meadow	62,707	62,702	-5	248,123	177,531	-70,592
Alpine scrub-meadow	8390	8651	+261	23,282	18,174	-5108
Pasture (converted forests)	8935	12,409	+3474	69,127	104,058	+34,931
Woodland pasture	14,324	18,970	+4646	30,463	29,580	-883
Subalpine scrub	83,924	103,210	+19,286	146,587	177,462	+30,875
Total	178,280	205,942	+27,662	517,582	506,805	+10,777

Table 2. Livestock development in Deqin County.

	Cattle/yak	Horse	Donkey	Mules	Goat/sheep	Total (cattle units)*
1986	53,451	1826	4515	1100	138,891	78,848.54
1989	57,275	3033	5121	1902	146,192	85,786.68
1993	54,960	3813	5345	2062	99,401	77,852.14
1994	58,444	7058	5314	1993	102,193	84,243.02
1995	59,284	3744	5697	2183	101,125	82,740.70
1997	62,050	4050	4612	2756	93,633	84,293.02
1998	62,426	4101	4645	3035	97,930	85,561.00

*: 1 cattle/yak = 0.14 sheep/goat = 0.8 horse/mules/donkey.

Change of pastoral output and meat production

In the last 14 years the output of livestock showed an apparent difference between yak/cattle and goat/sheep populations (Figure 1). The number of butchered yak/cattle has remained fairly steady, but the butchered goat/sheep numbers have fluctuated greatly, especially during the period before and after 1990. Generally speaking, Tibetan herders place high value on the yak. The yak is also generally thought to typify Tibetan pastoral production, but in much of the Tibetan pastoral areas sheep and goats are more important economically, especially for income generation. Sheep and goats require more care and

attention than yak but can deliver handsome economic returns where it is practical to raise them. Since they generally give birth every year, sheep and goat are important animals for restocking following heavy losses during severe winters (Miller 1998), but are also much more susceptible to winter kill. Moreover, goat/sheep production is more readily influenced by market fluctuations, so yak herds provide a steadier base for a pastoral household against natural or economic disasters.

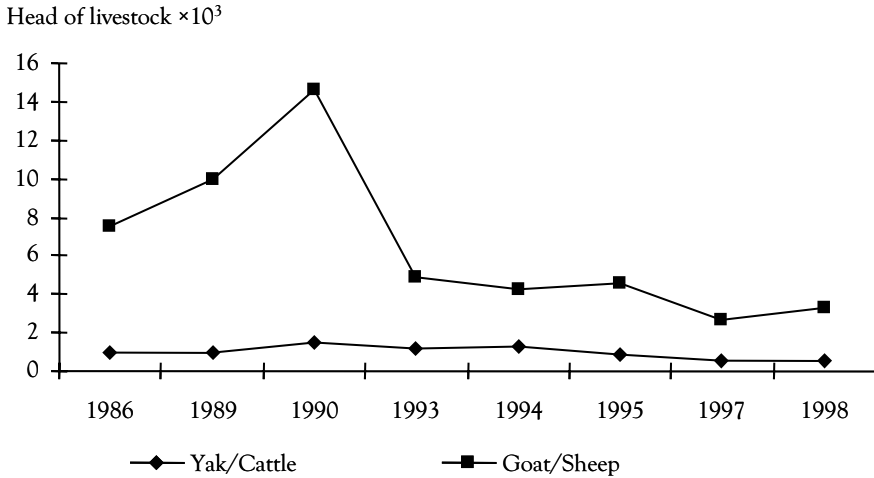


Figure 1. Change in butchered head of livestock in Deqin County.

Since 1993, the output of meat and other products decreased compared to sheep wool production (Figures 2 and 3). The yield of milk remained steady due to the maintenance of yak herds. The output rate of livestock in CU (cattle unit) was only 2.5% in 1986 and 1.2% in 1998. The development of pastoral output seems more in relation with marketing demands rather than with the number of livestock.

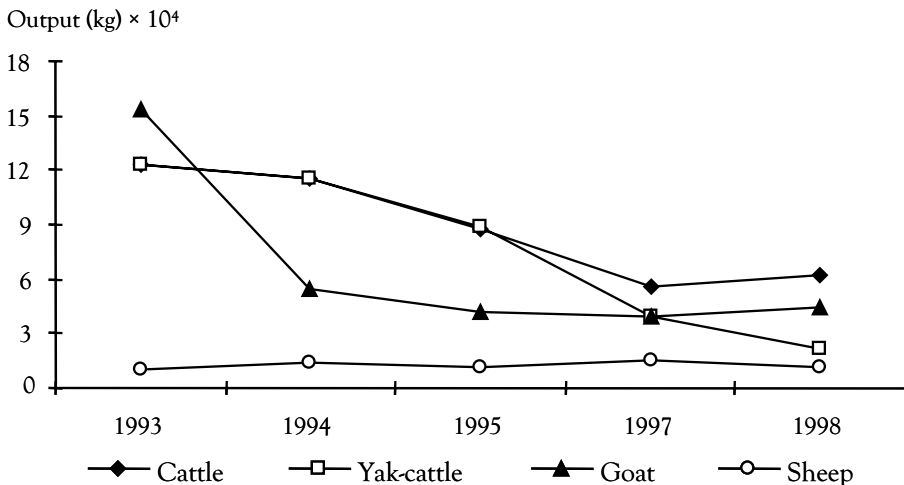


Figure 2. Meat production in Deqin County.

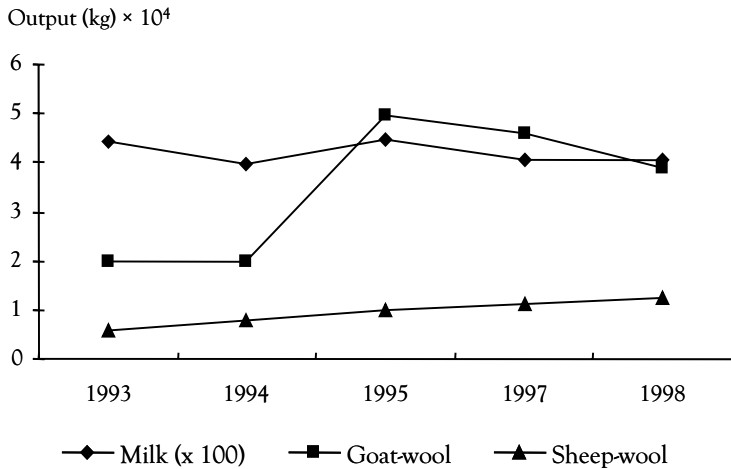


Figure 3. Milk and wool production in Deqin County.

Socio-economic development in relation to the pastoral production systems

The gross output of animal husbandry in Deqin County made up 33.1% of the local GDP in 1986 and 36.5% in 1999, but grazing lands only cover about 30% of the land surface. With the population density of 8 persons/km², this mountainous county supports about 55 thousand people, among which Tibetan people make up 82% with most depending on livestock for subsistence. The shortage of infrastructures such as roads, communication and marketing outlets hinders the economic development of the livestock sector, with only 10% of the output being sold to markets.

However, livestock production is playing an important role in local economies. Since the logging ban on natural forests was issued in October 1998, the most important income for local communities has been interrupted. Animal husbandry and tourism have become the main sources to generate government revenue. Increasingly, development programmes will be sponsored to accelerate the modernisation and commercialisation of pastoral production.

Discussion

The results above have displayed that the features of the pastoral production systems in Deqin County are a typically subsistence one. In view of the development in the last 14 years, this system has been facing a number of problems, some of which are also common in pastoral areas elsewhere.

Rangeland degradation

Rangelands degradation was reported in the 1980s when the government rangeland survey was finished. Production of pastures in alpine meadows and alpine scrub-meadows

appeared to have declined more than in subalpine pastureland (pastures among forests, thinning woodland-pasture and subalpine scrub). Compared to 1986, in 1999 edible biomass of alpine meadow and alpine scrub-meadow declined by 28.4% and 21.9%, respectively (Table 1). Despite the enlargement in subalpine grazing land area, the edible biomass of pastures among forests, thinning woodland-pasture and subalpine scrubs, decreased by 12.6%, 17.2% and 6.9%, respectively from 1986 to 1999. The greater decline in alpine rangelands could be ascribed to the harsh conditions such as erratic precipitation and cold temperature. When the population density of livestock increases continuously, overstocking is unavoidable and degradation of pastures occurs at the points where livestock gather, for example, water sources and settlements. Moreover, the degraded pastures are difficult to regenerate due to the high altitude environment.

Overgrazing

A key factor causing unsustainability of the pastoral production system is overgrazing on pastures in the long-term. Although the total CU (cattle unit) of livestock has not changed greatly in the last 14 years (Table 1), the grazing pressures on different pastures have shifted. Because of the expansion of farming fields and reforestation blocks, the period of herders and their livestock having to stay in summer/fall pastures both in alpine meadow and alpine scrub-meadow was longer than they traditionally practised. The overgrazing phenomenon of summer/fall pastures therefore was found to be more serious than winter/spring pastures. The upward expansion of sedentary farming has partially expelled herders out of their winter pastures, which has further shortened the traditional routes of seasonal migration of livestock and increased grazing pressures on alpine meadows. Although enlarging the grazing area in the subalpine zone is a potential option to lighten the pressures on higher altitude pastures, grazing livestock in reforested areas is thought to negatively impact the forest restoration and the conservation of water and soil.

Extensive management

Animal husbandry in Deqin depends mainly on natural pastures, and is practised as a low-input transhumance system. Owing to the uncertainty of environment, yak husbandry in these conditions has been always a high-risk enterprise. Historically, only a few forage plants are planted around winter houses. Crop residues are also used as hay during the winter. Traditionally, herders must migrate between summer pastures on mountains (alpine meadow) and winter pastures in valleys. Just as other pastoral areas on the Tibetan Plateau, with the development of livestock production, the key to improve livestock productivity is providing animals with enough forage throughout the year. The winter and spring are the main forage deficit times, so in the future more attention needs to be directed towards providing more forage, either in the form of grazing or hay that is made from native grass or artificial (exotic) pasture.

Inbreeding

Because of extensive management on yak production, crossbreeding and hybridisation for improving yak production have not been carried out to a great extent. Continuous inbreeding of the yak population impacts the productive performances of yak. Inbreeding among yak in Deqin could be impacted by changing pattern in migration, although this is mere speculation at this point. Changing from a mobile system to a more sedentary system has potentially led to the decrease of gene exchange among yak populations. Yak-cattle hybrids are very important in Deqin, because they can adapt to the local environment very well and provide packing and ploughing labour. However, the hybridisation practices between yak and cattle should also be systematised and improved with the help of modern genetic technology.

Sustainable development

Striking a balance between the conservation of rangeland and forest resources and pastoralism in light of increasing demands from people is crucial for the sustainable development of the region. Resolving rangeland management and pastoral development issues mentioned above require that ecological principles regulating rangeland ecosystem functions be linked with economic principles governing livestock production and general economic development processes. It should be stressed that there are no simple solutions to readdress pastoral development in the harsh environment of the Tibetan Plateau and due to the multifaceted dimensions of the problems; actions will need to be taken at several levels. Based on the situation in Deqin, four suggestions are proposed as follows:

1. Yak has better adaptability to the harsh environment of Deqin than any other bovidae animals. Therefore, the systematic selection of yak and the *in situ* conservation of the yak gene pool should be carried out immediately, which will become an important base for the sustainable development of yak husbandry.
2. Regeneration and rehabilitation of degraded rangelands should be given more attention so that the base of pastoral livelihood can be conserved. Furthermore, it is necessary to conduct research on fodder and hay meadows development for winter-feeding. If there is not enough forage provided to yak and/or their hybrids, their milk, meat and hair production potential cannot be realised.
3. Livestock output should be increased so that it cannot only provide more products to satisfy human demands but also reduces the grazing pressures on rangelands. This requires improving social services and market outlets for animal products on part of the government.
4. It is imperative to raise the level of technical capacity through training and technical exchange in pastoral areas and to survey socio-economic problems associated with yak production. The relationship between the dynamic nature of high-altitude rangeland ecosystems and yak management systems must also be understood thoroughly in the near future so that the grazing density of yak population could be better managed.

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The yak population in Mongolia and its relation with snow leopards as a prey species

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Summary

There are currently about 1000 snow leopards in Mongolia with an overall density of 1.10 cats per 100 km² of occupied habitat. These cats occupy an area range of probably less than 90 thousand km². The snow leopards commonly use terrain that is extremely rugged, in the same habitat where yak graze and often unguarded. Consequently, they, along with horses, are often killed by snow leopard, more so than other large livestock. During our study, 168 faecal samples of the snow leopard were collected and analysed. Results show that ibex made up 38.7% of the total diet, small mammals 4.6%, red deer 2.4%, marmot 7.1%, and domestic livestock 31% (including sheep 17.3%, horse 5.4%, cow 4.8%, and goat 3.6%). In addition to prey, vegetation (14.9%) and soil (2.3%) were also found in the faecal samples.

Keywords: Mongolia, prey species, snow leopard, yak population

Introduction

The status of snow leopards in Mongolia has only been superficially dealt with prior to 1989 (Bannikov 1954; Bold and Dorjzunduy 1976; Mallon 1984; Zhirnov and Ilyinsky 1986; O’Gara 1988). The cat’s approximate distribution in Mongolia is known but little information on snow leopard numbers is available. Dash et al. (1977) suggested that snow leopards generally occur in areas where ibex (*Capra ibex sibirica*) are present, and that the goat is a principal component of the cats’ diet. Mallon (1984) concluded that snow leopards are widely distributed in the mountains of western Mongolia but are not common and have likely declined in numbers during this century. They were thought to occur in the Altai Mountains, the Khangai Mountains, the Hanhoohy Uul and Harkhyra ranges, and in isolated mountainous sections of the Trans-Altai Gobi (Mallon 1984; Schaller et al. 1994) with an area probably totalling less than 90 thousand km² (McCarthy et al. 2000).

Population estimates for snow leopards in Mongolia have ranged from a few hundred to more than 4000. It is believed that about 1000 currently exist with an overall density of 1.10 cats per 100 km² of occupied habitat. The habitat characteristics of the snow leopard population have also been assessed (Schaller et al. 1994). Yak graze in the same habitat as a

snow leopard and are often left unguarded. Consequently, they, along with horses, are often killed by snow leopard, more so than other large livestock.

The yak population in Mongolia

Approximately 4.6% of the grazing land of Mongolia is located in the high mountain regions and is suitable for yak to graze. The average altitude is above 3700 metres above sea level (masl). Though the livestock population of Mongolia was relatively constant for 60 years, their numbers increased rapidly over the last 10 years (by about a million/year, reaching 33.4 million in 1999) as Mongolia underwent a transition period from socialisation to the market economy and as livestock became privatised. The number of yak also increased in this period, by 42.5% between 1994 and 1999, so that there are now 813,300 yak registered in Mongolia. The main population of yak are located in the high Altai Mountain range, the Khangai Mountain range and the Kharkhiraa and Khovsgul mountains. In the Gobi Altai Mountains and Gurvansaikhan, there also is a limited number of yak in the higher pastures.

Snow leopard diet analysis—methodology

Field surveys to determine snow leopard diets have been undertaken in Mongolia for the last decade, especially in western and southern Mongolia where snow leopards predominate. During these trips, 168 snow leopard faecal samples were collected and analysed.

Collected faeces were dried out in the air directly after collection in the field, and stored into bags. To ensure that samples were authentically from snow leopards, they were collected adjacent to snow leopard signs such as scrapes and scent sprays or claw rakes. At the laboratory the remains of prey species were separated and dried. To identify hair remains, hair samples were collected from domestic livestock, live wildlife and stuffed specimens in museum collections, and used to prepare original slides for identification following the methods outlined by Teerink (1991) and Oli (1993). The remains that could be identified were tabulated by species name. The remains of small mammals (in the form of bones, hair etc.) that could not be determined by species were simply classified under the general heading 'small mammals'.

Results and discussion

Snow leopards (*Uncia uncia*) in Mongolia mainly feed on ibex (*Capra ibex sibirica*), argali sheep (*Ovis ammon*), pika (*Ochotona sp*), hare (*Lepus tolai*), marmot (*marmota sibirica*), snowcock (*Tetraogallus altaicus*), chukar (*Alectoris chukar*) and livestock (including yak). They sometimes also feed on Mongolian goitered gazelles (*Gazella subgutturosa*), red deer (*Cervus elaphus*), roe deer (*Capreolus pygargus*), young bears (*Ursus arctos*) and other wildlife. Bold and Dorjzunduy (1976) collected and analysed 50 faecal samples of snow leopards from the

region of South Gobi, Tost Mountain. A total of 82% of the samples contained wildlife remains, mostly ibex hair.¹

Schaller et al. (1994) collected 29 faecal samples of snow leopard during a month-long-field survey. The main food items found were ibex (62.8%) and marmot (17.6%), in addition to yak (2.6%) and vegetation remains (17%). The results of Amarsanaa's (1985) study to determine the winter diet of snow leopards at Burkhan Buudai Mountain in the Altai Mountain ranges are tabulated (Table 1). The study was based on the analysis of 32 faecal samples.

Table 1. Winter diet of snow leopards at Burkhan Buudai Mountain.

Prey species	Cases	Percentage
Ibex	15	46.9
Chukar	4	12.5
Yak	4	12.5
Horses	3	9.3
Argali sheep	2	6.3
Hare	2	6.3
Pika	1	3.1
Snowcock	1	3.1
Vegetation	1	3.1

Source: Amarsanaa (1985).

In our study, a total of 266 remains of various food items such as bones, hair etc. were found in the 168 analysed samples of snow leopard faeces. Five samples (3%) of the total 168 contained the remains of three prey species, 53 samples (31.5%) contained the remains of two prey species, and 109 (64.8%) contained the remains of one prey species. We were not able to determine the content of one sample. The results of the analyses for both sites (see Table 2) show that ibex made up 38.7% of the total diet, small mammals 4.6%, red deer 2.4%, marmot 7.1%, and domestic livestock 31% (including sheep 17.3%, horse 5.4%, cow 4.8% and goat 3.6%). In addition to prey, vegetation (14.9%) and soil (2.3%) were also found in the faecal samples.

In this initial survey, snow leopard appear to feed mainly on ibex and small mammals. This result could partially be attributed to the fact that we collected snow leopard faeces in July, August and October (Table 2). However, we tried to determine roughly the age of 59 of the snow leopard faecal samples by season. Of this sub-sample, 12 were dated from the autumn, 6 from the winter, 6 from the spring, and 35 from the summer. Analysing this small amount of data by season proved to be difficult, but we present our preliminary results in Table 3. The seasonally disaggregated data suggest that snow leopards are feeding mainly on ibex and sheep during the winter, on sheep and horse during the spring, and on small mammals and ibex during the summer and autumn months.

1. Twelve samples contained the remains of grasshopper, ibex and vegetation; 12 samples contained chukar (*Alectoris chukar*) and blue hill pigeon (*Columbia rupestris*) remains; 3 samples contained hare remains; 8 samples contained mostly ibex hair; 9 samples contained vegetation remains; and 6 samples contained the brown colour remains of blood and meat of unknown animals.

Table 2. Snow leopard diet in Uvs and South Gobi Provinces.

Prey species	Uvs		South Gobi		Total	
	Cases	Percentage	Cases	Percentage	Cases	Percentage
Small mammals	35	46.7	43	46.2	78	46.4
Ibex	24	32	41	44	65	38.7
Sheep	19	25.3	10	11	29	17.3
Vegetation	15	20	10	11	25	14.9
Soil	3	4	9	9.7	12	7.1
Horse	2	2.7	7	7.5	9	5.4
Cow	3	4	5	5.4	8	4.8
Pika	-	-	10	11	10	4.4
Goitered gazelle	-	-	6	6.5	6	3.6
Goat	2	2.7	4	4.3	6	3.6
Marmot	2	2.7	-	-	2	2.7
Red deer	4	5.3	-	-	4	2.4
Birds	3	4	1	1	4	2.4
Insects	4	5.3	-	-	4	2.4
Hare	2	2.7	-	-	2	1.2
Roe deer	1	1.3	-	-	1	0.6
Ground squirrel	1	1.3	-	-	1	0.6
Unknown	-	-	1	1	1	0.6

Table 3. Snow leopard diet by seasons.

Prey species	Winter		Spring		Summer		Autumn	
	No.	Percentage	No.	Percentage	No.	Percentage	No.	Percentage
Ibex	4	67.7	-	-	13	37.1	7	58.3
Small mammals	1	16.7	1	25	16	45.7	7	58.3
Sheep	3	50	4	100	5	14.3	1	8.3
Red deer	-	-	-	-	2	5.7	1	8.3
Cow	1	16.7	-	-	1	2.85	1	8.3
Goat	-	-	1	25	2	5.7	-	-
Horse	-	-	2	50	1	2.85	-	-
Marmot	-	-	-	-	2	5.7	-	-
Birds	-	-	-	-	1	2.85	-	-

We attempted to calculate biomass used by snow leopards using the following formula:

$$D = B \times C \quad (B = Y = 1.98 + 0.035 \times A)$$

where A = average weight in kg; B = biomass per faeces sample in kg; C = number of samples containing a certain species; D = biomass of prey used.

In this case study we found that the main diet items of the snow leopard were ibex, small mammals, sheep and horse (Table 4).

Table 4. Biomass used by snow leopards.

Prey species	Average live weight (kg)	Biomass per faeces (kg)	No. of faeces containing species	Biomass used (kg)
Ibex	80	4.81	65	312
Small mammals	0.2	2	78	156
Sheep	30	3	29	87
Horse	140	6.9	9	62
Marmot	4.5	2.1	12	25.2
Goat	25	2.9	6	17.4
Birds	1.5	2	4	8
Hare	3.5	2.1	2	4.2

In this study, we found ibex to be one of the main prey species of the snow leopard. The study areas at Uvs and South Gobi, which have been protected since 1970, have very good populations of ibex in pasture areas not used for grazing. When the results of this study, conducted in areas where wildlife are adequately protected, are compared to studies conducted in areas with more livestock occupied areas, the snow leopard diet analyses show that wild prey species make up more of the snow leopard's diet than domestic livestock in protected areas. Possible explanations for this may be either that livestock have replaced wild prey in some pasturelands or that livestock are simply easier to kill than their wild counterparts, or perhaps both.

The percentage of goat in the snow leopard diet in Uvs, and even into the Gobi Gurvansaikhan National Park, is small compared to the results of previous research in other areas due to small herd sizes. In a study conducted by Bold and Dorjzunduy (1976), domestic goats accounted for 82.4% of total livestock predated by cats. Amgalanbaatar et al. (1999) did a similar study in the Tost and Nemegt mountains. In the past 20 years, predation on domestic goats by snow leopards has increased up to 87.8% because of a rapid increase in the goat population in response to demand for cashmere. However, in our study area, wildlife are well protected and goat populations are relatively small, thus the percentage of domestic goat in the snow leopard diet is reduced. This study suggests if wild prey populations are viable, herders may not need to worry so much about their animals. Another important food item found in this study was small mammals, most likely because we collected the faeces mostly in the summer and autumn seasons.

The snow leopard diet differs by region depending on the potential prey species and fauna in the regions. In the Yamaat valley of Turgen, which is strictly protected and contains an important red deer population, snow leopards usually locate along the forest borders and feed on the red deer. In the South Gobi, such as in Gobi Gurvansaikhan National Park, if the summer is hot and dry and goitered gazelles migrate up to the mountains looking for water resources and good grazing, they can be attacked by cats.

Snow leopards often kill horse and yak, which herders do not guard. As they are also farther ranging than other livestock, their pasture may also overlap with snow leopard habitat. In this study, yak remains were not found in the faecal samples and horse remains were significantly less than what we expected. The reason for this could be that the study areas are strictly protected and the number of domestic animals pastured there are few.

Another reason could be that in these areas the populations of wild prey species, such as ibex, small mammals and hare, are sufficient and thus easier prey for the snow leopard than either horse or yak.

Vegetation remains were found in many of the samples, especially in those collected in areas of more grassy terrain such as in the Turgen Mountains, as opposed to those collected in the barren terrain in the South Gobi. Conversely, more soil was found in the South Gobi samples than those from Uvs. Most likely the animals are ingesting vegetation and soil while eating prey.

Habitat assessment

The snow leopards commonly use terrain that is extremely rugged. Habitat quality for snow leopards is related to both physical and biological attributes. Leopards may use elevations between 900 and 5500 masl. However, in northern habitats such as western Mongolia they select ranges between 900 and 2500 masl. A strong affinity for steep and highly broken terrain has been well documented throughout their range (McCarthy et al. 2000). The presence and density of large mountain ungulates is also a strong measure of habitat quality. Finally, human use, both direct and indirect in the form of livestock grazing, is an influencing factor in habitat quality.

Yak in Mongolia reside in very similar habitat to snow leopards. Yak usually graze in high alpine pastures (mainly at altitudes above 2500 masl) and are left to roam freely in the mountains in winter without protection. Yak graze on 49 species of vegetation, the dominant types being *Cetraria*, *Betula*, *Kobresia* and *Cladonia* (Magash and Jaina, in preparation). They generally move 3–5 km/day while grazing and rest under cliffs where it is easier for snow leopards to catch them. Though yak and snow leopards ranges overlap in summer, snow leopards mainly preys on yak in winter when small mammals and marmots are not available. The snow leopard seems to prey on yak because 1) their respective ranges overlap, and 2) because yak are left unguarded while they graze. More work is needed to determine the actual extent of yak' depredation, including the extent of economic loss to herders, and means of controlling predation, if local communities deem it a major problem.

Acknowledgement

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Recent results of yak research in Western High Asia

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Summary

In this paper four case studies are introduced from Western High Asia, i.e. from the Western Kun Lun Shan and Pamir mountains. Yak keeping has been an important survival strategy for nomads and agropastoralists practising combined mountain agriculture (Ehlers and Kreutzmann 2000). During the 20th century significant transformations of production strategies took place, which have affected animal husbandry in general and yak keeping in particular. Recent results of fieldwork in different mountain communities in Western High Asia show the influence of political transformations and economic reforms. The main emphasis is put on the role of yak breeding within the specific production system.

Keywords: Agropastoralism, central Asia, mountain agriculture, nomadism, Pamir, yak keeping

Introduction

The importance of yak keeping in high mountain pastoralism can only be judged by taking into account its share in the overall agro-economic activities within mountain societies. The two major adaptive strategies of utilising the pasture potential of Western High Asia (Figure 1) under given ecological constraints occur in nomadic animal husbandry and in the livestock sector of agropastoral systems.

Nomadism embodies the advantage of mobility. Traditionally nomadic groups were able to exploit natural resources at dispersed locations. Great distances in the order of several hundreds of km separated economically valuable mountain pastures from winter campsites, with areas of less economic interest lying in between. The functional migration cycle involved seasonal stays in high-altitude summer pastures and low-lying basin pastures in the northern foothills or plains of the Inner Asian mountain ranges during the winter. In these areas the nomads relied on neighbouring communities to tolerate their presence and paid grazing fees, if necessary.

Agropastoralism has the advantage of fodder production in the permanent homestead areas to sustain herds during the winter months. These animals are then taken to high altitude summer pastures. The limiting factor here is the provision of sufficient feed during the critical winter period, forage that must be produced on limited private or common

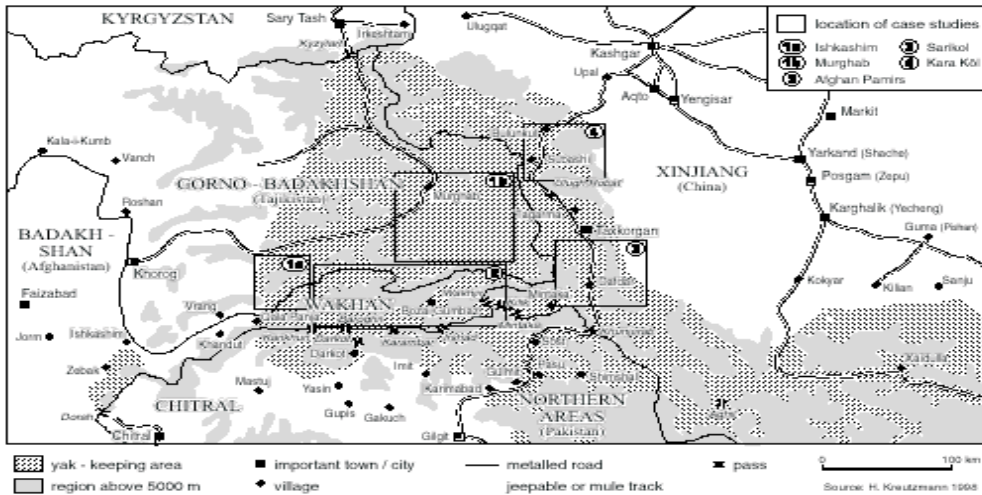


Figure 1. Yak keeping in Western High Asia.

village lands. Their permanent habitations are located at the upper levels of single-crop farming. The access to the Pamir pastures involves shorter migrations and some mobility within the summer pastures. Summer grazing is comparatively plentiful but only available for a short period; feed storage and transport to the homesteads are of limited importance.

Both approaches can result in competition for natural resources in the same location and have frequently been discussed from that perspective. The ecological aspect has been expanded to the debate about conflicting economic strategies (Ehlers and Kreuzmann 2000). In the discourse of modernisation and social change, the system of nomadism is often replaced by crop-based agriculture. The extensive utilisation of marginal resources is thus superseded by intensification.

Case studies from Western High Asia

The following case studies highlight historical developments that relate to the transformation of economies based on pastoralism.

Soviet sedentarisation programmes and recent developments in middle Asia

As the majority of the Pamirs is located within the Gorno-Badakhshan Autonomous Oblast of the Tajikistan Republic, they were involved in the sedentarisation process of nomads during Stalinist modernisation programmes in the 1930s. At that stage nomadic

production systems and associated life-styles were declared as backwards and in need of change. Since then the system of pasture utilisation has shifted to Kolchoz and Sovchoz settlement-centred seasonal migration of herds (Monogarova 1978).¹As Dachsleijger (1981) and Giese (1983) have pointed out for the Kazakhstan Republic, an overall advance in the productivity of agriculture followed a long period of decline (1930–1960). In addition to the extension of cultivated lands, fodder production was increased and improvement of the breeds and their health condition. Permanent winter stables with adequate infrastructure, veterinary treatment and sufficient fodder contributed to the development of the livestock sector and remnants of this system can still be seen today in existing Pamirian pastoral systems.

In the eastern Pamir, part of Tajikistan's Gorno-Badakhshan district, Kirghiz shepherds and a few Wakhi still keep yak herds around traditional supply stations like Murghab (formerly Pamirski Post) and Langar in Rajon Ishkashim from where they undertake seasonal migrations to the higher elevated summer pastures (Table 1). However, traditional nomadism was converted into a form of mobile animal husbandry under the conditions of Soviet-style collective resource management. Concurrently, agropastoral systems were also adjusted to the prevalent socio-economic set-up.

Table 1. *The regional distribution of the Pamirs.*

Eastern Pamir	Gorno Badakhshanskaja Avtonomnaja Oblast (GBAO) Republic of Tajikistan Khargushi Pamir (Pamir of the hare): the basin of lake Kara Köl (black lake) Rang Köl Pamir (Pamir of the coloured lake): the basin of the lake with the same toponym Sariz Pamir (Pamir of the yellow trail): part of the Murghab valley up to the settlement of Murghab (previously named Pamirski Post) Alichur Pamir: the valley of the river with the same toponym
Wakhan	Wakhan Woluswali, Badakhshan Republic of Afghanistan Chong Pamir: Great Pamir or Pamir-e Kalan: the headwaters of the Pamir Darya and the basin of Zor Köl (big lake) Kichik Pamir: Little Pamir or Pamir-e Khurd: the headwaters of Aksu river including the lakes Chakmaktin Köl and Besh Ötök Köl
Sarikol	Taxkorgan Tajik Autonomous County Uigur Autonomous Region Xinjiang, P.R. China Taghdumbash Pamir: headwaters of river with same name and Karachukur River

Source: Kreutzmann (1996).

Under Soviet rule, Tajikistan's economy was completely integrated into the system of a regional division of labour, which attributed each republic specific tasks. Significant effects were felt even in the remote mountain areas, as the case of Gorno-Badakhshan reveals. The

1. The Soviet collectivisation strategy created Kolchoz (Kollektivnoe Chozjajstvo = co-operative societies for agriculturalists who own the livestock and the agrarian means of production) and Sovchoz (Sovetskoe Chozjajstvo = state farms with employed agricultural labourers). In both cases the farmland is property of the government and the enterprises are state-run.

Wakhi members of sovchoz roi kommunizm (literally meaning state farm ‘path of communism’) in Rajon Ishkashim kept yak in the upper parts of the Amu Darya valley and in Khargushi Pamir. The whole agricultural system was devoted to animal husbandry, and all other food supplies were imported from outside. Even high-protein fodder was brought in to sustain yak herds throughout the year in the Pamirs (approximately 50 tonnes/450 yak).

With the independence of Tajikistan and the subsequent transformation process, individual ownership of land (1996–1999) and cattle were re-introduced. Yak herding is organised through farmers’ associations. Shepherds keep 70% of their production while the rest belongs to the association. The Wakhi of Ishkashim are the only non-Kirghiz yak herders of the western Pamir and still control a herd of 300 yak.

The Soviet state-run economy had selected the eastern Pamir as the prime yak producing region and mainly Kirghiz pastoralists had been involved. Even today nearly 14,000 yak are kept in Rajon Murghab. To date, the majority of yak herds are controlled by state-run enterprises or farmers’ associations, which are the follower organisations of Kolchoz and Gozchoz.² The adverse economic conditions of the transformation period have impoverished the Kirghiz herdsmen, as herds are small, food supplies meagre and additional food from the market expensive. Consequently, the vast majority of agriculturists in Gorno Badakhshanskaja Avtonomnaja Oblast (GBAO) are dependent on humanitarian aid. The situation was aggravated by substantial losses of livestock in February/March of 1999 when, in Rajon Ishkashim alone, 5000 heads of yak were lost to unexpectedly high snowfall. The socio-economic transformation process has forced the majority of people to follow a subsistence strategy based on agricultural and livestock resources. The present income levels are far below previous ones and it remains to be seen if this resource-based strategy will succeed.

Kirghiz exodus from the Afghan Pamirs

The Great and Little Pamir within Wakhan Woluswali of Badakhshan Province (Afghanistan) have been studied extensively up to the so-called ‘last exodus’ of the majority of Kirghiz nomads to Pakistan in 1978. Their fate is one of the more prominent cases where border delineation has interrupted traditional migration patterns and where the term ‘closed frontier nomadism’ was coined (Dor and Naumann 1978; Shahrani 1979; Shahrani 1980; Shahrani 1984).

Impoverished Wakhi farmers utilising the Pamirs for summer grazing competed with rich Kirghiz nomads who controlled most of the grazing resources of the region. Consequently, the Wakhi became shepherds for Kirghiz herd owners and turned eventually to nomadic strategies (Kreutzmann 1996). At the peak period prior to the exodus, the share of yak was about 8% of the total community’s herds, which amounted to about 42,000 animals (Shahrani 1979).

In 1978 a group of 1300 Kirghiz (280 yurts) fled to Pakistan. Not all members of the Kirghiz group of Rahman Kul—the leader (khan) of the community and most influential

2. Gozchoz is another term applied for a state-run farm.

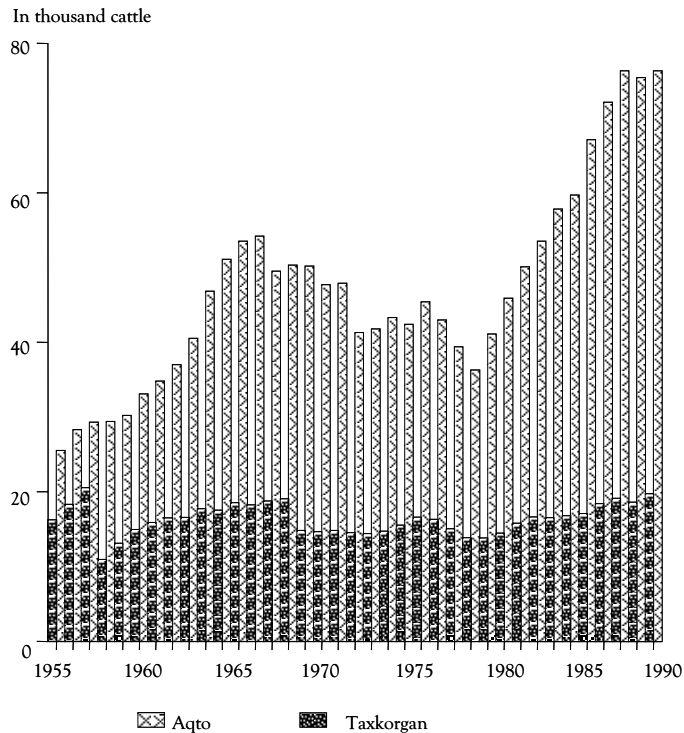
person of the Afghan Pamirs—joined him after four years of exile in Pakistan to eastern Anatolia. Rahman Kul alone had to leave 16 thousand sheep and goats, more than 700 yak, 15 horses and 18 Bactrian camels behind, while the whole community of the Afghan Pamirs possessed no more than 42 thousand animals. Of this only a small herd of 6000 could be taken to exile in Pakistan, and eventually none ever left Pakistan. Rahman Kul migrated with a group of 1132 Kirghiz in August 1982 to Turkey. He became the village head of the community in Ulupamir Köy, 1800 metres above sea level (masl), as a member of a government resettlement scheme, which provided each household with 10 sheep and goats and three head of cattle. Rahman Kul died there in 1990 and the leadership was transferred to his son. Presently this community has grown to 2000 members practising sedentary agriculture and animal husbandry with their herds of 7000 sheep, 1000 goats, 6000 cattle (no yak) and 70 horses (Gundula Salk, Berlin; Bernard Repond, Marsens, Switzerland, personal communication). A small group of 200 Kirghiz returned to the Little Pamir from Pakistan by October 1979 (Shahrani 1984). The community under the leadership of Abdurrashid Khan had grown to 102 yurts in Pamir-e Kalan (Great Pamir) and 135 yurts in Pamir-e Khurd (Little Pamir) by 1999. The number of cattle ranges around 1400 compared to nearly 9000 sheep and goats, 160 horses and 90 Bactrian camels. Any form of animal husbandry has been limited to subsistent survival strategies in recent years as traditional migration and exchange patterns have been interrupted due to adverse political conditions. Currently the Kirghiz are engaged in yak breeding and in limited barter trade with entrepreneurs from neighbouring Hunza in Pakistan. The itinerant traders supply basic necessities in exchange for yak and yak products. Nevertheless, humanitarian aid from outside is regularly needed for basic food supplies.

Competition between nomads and mountain agriculturists in the Pamirs (Sarikol)

The Taxkorgan or Sarikol (name of the former principality) area comprises three different ethnic groups: Sariqoli, Wakhi and Kirghiz (the latter less than 5% of the population). The former two groups (82% of the inhabitants) are agropastoralists with seasonal utilisation of Pamir pastures, while the Kirghiz solely specialise in livestock husbandry. All three groups traditionally move their flocks within the Taghdumbash Pamir and paid tribute to the Mir of Hunza who exercised control on these pastures until 1937 (Kreutzmann 2000). While Kirghiz permanently resided in the higher elevation areas, Sariqoli approached from the northern low-lying villages. The Wakhi founded their settlement of Dafdar, 3400 masl, in the heart of the Taghdumbash Pamir about a century ago, with the consent of the Chinese authorities. All three groups compete for the fodder resources.

After the Chinese revolution in 1949 and the formation of the Tajik Taxkorgan Autonomous County in 1954, collectivisation took place and rural communes were established in the villages. Basic infrastructure has been provided to all communities of the Taghdumbash Pamir such as schools, police posts, health posts, medical facilities, commune administration and shops, mosques etc.

The number of livestock increased by a factor of 4.75% up to 128,800 heads in post-revolution times (Figure 2). During the following decade the growth slowed down, and in 1994 the number of livestock ranged at about 147,586. This figure covers all livestock types: Bactrian camels, horses, donkeys, yak, other cattle, sheep and goats. Natural grazing provides the most important local forage resource. The area covered with grasslands extends to 6.09 million mu (1 hectare = 15 mu) of which 98% belong to natural grazing while 0.13 million mu are irrigated meadows (Table 2). More than two-thirds of the income of Taxkorgan County is derived from animal husbandry, e.g. in 1984 2.75 million RMB Yuan (US\$ 1 \approx 3.7 Yuan in 1984), compared to 1.18 million Yuan from crop production alone (Kashgar Prefecture Chronicle 1985).



Source: Livestock Department, Taxkorgan, Aqto Tāzkirisi (1991).

Figure 2. Cattle in Aqto and Taxkorgan County 1954–1990.

By 1960, for the first time since the Chinese Revolution, self-sufficiency in food and fodder production was achieved in Taxkorgan County (Xinjiang). Since 1982 the majority of the eleven townships and former people's communes (Renmin Gongshe) has been equipped with a veterinary station supplying vaccines and extension services to the farmers. Experiments with fat-tailed sheep (dumba, dumbash) have been executed and their share in the regional flocks has been increased (Schwarz 1984). In the heart of the Taghdumbash Pamir a veterinary station specialised on yak breeding was established in Mazar (south of Dafdar along the Pakistan–China Friendship Highway) by utilising the local knowledge of

Tajik and Kirghiz shepherds who found employment there. About 400 persons reside in Mazar breeding farm, which contains about 5000 sheep and 500 yak (Schaller et al. 1987). The Wakhi and Kirghiz of the Karachukur Valley that drain the westernmost part of the Taghdumbash Pamir kept much bigger herds of yak. This side of the valley has become the only Kirghiz-dominated pasture region of the Taxkorgan County. The number of yak grew from 5909 in 1981 to 8147 in 1990, the highest figure since 1976. The trading and export value of yak have been limited, only rarely small consignments of yak were exported to the neighbouring Hunza valley in Pakistan. In recent years this transborder business has ceased to exist. Yak are now mainly used for local purposes, principally milk, butter, qurut (dehydrated buttermilk which can be preserved and stored), hair and meat. Additionally, their transport capabilities and adaptability to the harsh terrain are regarded as major assets in the Chinese Pamirs.

Table 2. Potential fodder availability of pastures in the Pamir regions.

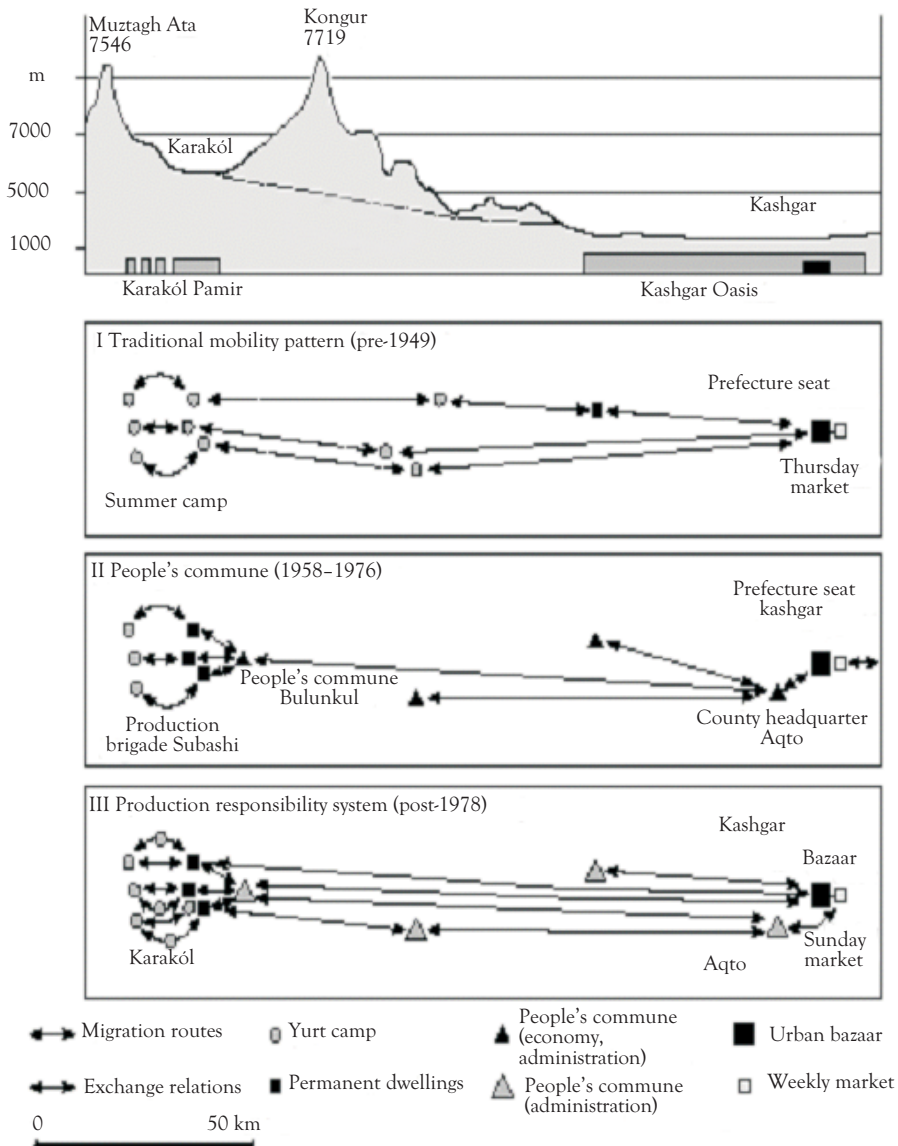
Region	Grazing area			Available grazing potential				
	Total area (ha)	ha	%	Used		Not used		Total
				Tonnes	%	Tonnes	%	Tonnes
Western Pamir	2,468,700	1,113,390	45.1	40,990	22.4	141,260	77.6	181,250
Wakhan	249,200	146,030	58.6	2630	17.8	12,120	82.2	14,750
Eastern Pamir	2,839,700	1,099,900	38.7	61,400	45.3	74,400	54.7	135,800
Total Pamir	5,308,400	2,213,290	41.7	102,390	31.9	215,660	68.1	317,050
Sarikol (Taxkorgan)	5,038,250	374,313	7.4					555,370

Source: Walter and Breckle (1986); and data from Taxkorgan county administration 1991, 1998.

Kirghiz pastoralists in Kara Köl

The Kirghiz of Kizil Su followed traditionally a long-distance nomadic migration cycle between the summer grazing grounds in the Pamirs and the irrigated oases of the mountain forelands. They spent the winter engaged with herding and other business in the towns of Kashgar and Yarkand. The former pattern has changed within the last 50 years (Figure 3). Nowadays the Kirghiz nomads are confined with their herds to the Pamir regions year-round. They now only leave their mountain abodes and travel on foot with their flocks or on trucks down to the markets of Kashgar and/or Yarkand. The herds cover the distance of 280 km easily and without great loss of weight.

The pasture system has changed to reflect the prevailing socio-economic conditions. The herds of the Kara Köl Kirghiz consist on average of 1.5 horses, 1.4 donkeys and 2.5 Bactrian camels per household. These animals are preferable for transportation and travelling purposes. Additional livestock comprise on average 12.2 yak, 98.2 sheep and 40.1 goats (Kreutzmann 1995). In comparison, in 1976, the people's commune of Subashi (Karakul) owned only 0.5 horses, 0.3 camels, 3.5 yak and 74.9 sheep and goats per household. The total number of livestock ranged around 10,300 animals in this period (Myrdal 1981), of which households in the commune privately owned a small amount. The carrying capacity of accessible pastures was estimated to be 40 thousand animals. By 1991



Design: H. Kreutzmann

Figure 3. Mobile livestock economy and change relations of Kirghiz pastoralists in Kara Köl.

the number of heads had reached 30 thousand. The growth of livestock in Kara Köl is out of proportion in comparison with the overall livestock development in Aqto division where livestock numbers grew by 1.3% from 1976–91 and cattle numbers by 1.65%, respectively (Aqto Tāzkirisi 1994). In the remote, high altitude yak and sheep-breeding area, the livestock numbers grew three times faster. In this area relaxed attitudes of the Chinese authorities towards agricultural and livestock production and especially since the reforms of 1978 have led to an increased market orientation. The quality of pastures was improved by irrigation and fencing of meadows. Grass is cut by scythe and winter fodder is stored to cover

the long period of meagre natural grazing in the winter settlement (kishlok) of Subashi at an altitude of 3600 masl.

Administratively, the Kara Köl grazing zone forms part of the Aqto division, which is one of the four subunits of the Kizil Su Autonomous Oblast where the majority of China's 119,300 Kirghiz reside (data of 1994). The majority of the Kirghiz of Kizil Su have become sedentary agriculturists while the inhabitants of the higher Pamirs continue to follow mobile livestock rearing. The kishlok of Subashi is equipped like other communes with infrastructure institutions as well as a veterinary post controlling the quality and health status of animals. Despite the harsh environmental conditions animals raised in these productive pastures compete very well in the profitable markets in the urban oases along the southern Silk Route (Tarim basin).

Role of yak

In all four cases presented, yak keeping has played a major role as yak are well adapted to this high-altitude environment. Our observation is that wherever animal husbandry is a persistent economic feature yak remain an important component of the herds. The data available basically show steady figures for yak while the remaining stock varies much more widely.

An important exception has been observed in northern Pakistan where in the Hunza region yak numbers have risen in recent years (Kreutzmann 1986; Kreutzmann 2000). Within the last decade stocks of yak have been expanded through the import of female yak from the Taghdumbash Pamir in Xinjiang (China) across the Khunjerab Pass and the Karakoram Highway into the Northern Areas and mainly Ghujal subdivision of Hunza (Figure 1). In 1989/90 alone more than 500 yak were imported of which one-third was retained for breeding purpose and the rest replenished the consistently deficient meat market of Gilgit. This deficit has enticed local entrepreneurs to rear yak herds to market them in the meat bazaars of the Northern Areas. The quality of locally raised yak is by far higher than the appalling low-quality meat of water buffaloes imported from down-country Pakistan. In recent years, yak have been bartered with the Kirghiz of the Afghan Pamirs. The supply of fresh meat has resulted in the opening of butcher shops in villages such as Gulmit where such a business existed never before. This exceptional feature puts yak into the picture as a marketable resource. However, in most of the cases the role of yak is quite different. Only the extreme deficit in meat supplies has affected the pattern observed in Pakistan.

In general, yak herds are primarily kept for subsistence purpose and as a risk-adverse investment. With comparatively low labour input, substantial live meat reserves are kept in these yak herds. Besides that, there are further spin-off effects in milk and hair processing, and other enterprises. Thus yak keeping complements combined mountain agriculture as part of a multi-faceted survival strategy under high altitude conditions. The higher the settlement regions the more importance placed on crop-livestock production. These agropastoral systems are characterised by the cultivation of well-adapted cereal crops, integrated with inputs from livestock, which provide dung, fuel and traction power and

human food. Yak play a prominent role in this respect when the search for security during difficult times is of high priority.

Other bovines and especially sheep and goats are predominantly kept for marketing purposes. Consequently their numbers have varied much more under changing socio-economic conditions. In the context of planned economies a shift to fat-tailed sheep and goats is observed, a trend that has gained in momentum after the relaxation of rules and regulations. These animal herds are basically responsible for dramatic changes in vegetation cover and for land degradation. In the Kara Köl Pamir their numbers have tripled since the reforms of the late 1970s and fat-tailed sheep are in great demand in the urban markets in the foothills of the mountain ranges.

Yak keeping seems to be a less important indicator for socio-economic change in Western High Asia. Nevertheless, yak play a vital role in the domestic economy, especially as a subsistence base during times of duress. Livestock keeping has always been a risky undertaking in high mountain regions. The safety factor is best served if yak herds are maintained, as they are the best animals to utilise the marginal pastures in the remote Pamirs.

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The cultural ecology of yak production in Dolpo, West Nepal

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Summary

This paper presents the salient aspects of agropastoralism as it is practised in the Dolpo region of western Nepal. Dramatic political and economic forces are encroaching upon and changing Dolpo's way of life. Amongst these changes are the closing of the Tibetan border during the 1960's and the increasing availability of cheap goods and commodities like salt from the southern regions of Nepal. The effects of these changes upon the traders and pastoralists of Dolpo have been dramatic and their story is one of adapting—economically, culturally and ecologically—to shifting resources and shrinking economic niches. Social institutions and geographical circumstances in Dolpo have helped maintain this transhumance system unto the present. However, government policies have undermined the resilience and viability of this way of life.

Keywords: Agropastoralism, cultural adaptation, Dolpo, indigenous knowledge, Nepal-Tibet border, rangeland management, Trans-Himalayan

Introduction

Dolpo encompasses four rugged mountain valleys in the Trans-Himalayan region of north-west Nepal. This region is home to Tibetan-speaking, Buddhist pastoralists who live in some of the highest altitude villages in the world. Dolpo is within Nepal's largest district and is today one of the least developed and most sparsely populated regions of that country: there are no roads, literacy is low, family planning is absent, and life expectancy reaches a mere 50 years (Bajimaya 1990; Sherpa 1992).

The Dolpo region falls within the rainshadow of Mt Dhaulagiri, the sixth highest mountain in the world (8172 m or 26,790 ft). As a result, climatically speaking, Dolpo experiences sharp seasonal differences in temperature and rainfall, has a short growing season, recurring droughts, high winds, and heavy snow falls, all creating rigid constraints on plant growth. Rangelands are the dominant ecosystem type in the Trans-Himalayan. Dolpo's rangelands are typified by high seasonal variation in forage quantity and quality. The period of plant growth is quite short—between May–October—so the movements of people and animals are closely synchronised with these brief windows of ecological opportunity.

Transhumance has been practised continuously in Dolpo for more than 1000 years (Miller 1993). Transhumance in Dolpo is characterised by movements from permanent villages to rangelands at different altitudes, a pattern more regional than the wide-ranging pastoral nomadism of central Asia (von Furer-Haimendorf 1975). There is only one agricultural harvest per year and consumption exceeds production (Jest 1975; Bajimaya 1990; Sherpa 1992; Valli and Sommers 1994), so the people of Dolpo must supplement their household production, using livestock to synergise trade, commodity production and agriculture.

For centuries, the people of Dolpo profited from their strategic position in the transition zone between the Tibetan Plateau and the Himalaya by being middlemen—climatic and cultural straddlers—in a commodities trade between farmers from the hill regions of Nepal and nomads on the arid plains of south-western Tibet. The villagers of the more mesic environment south of Dolpo produce annual surpluses of crops like corn and millet. However, they need salt. Likewise, the rangelands of the Tibetan Plateau sustain pastoral production, but its extreme climate precludes crop cultivation. This surfeit and shortage of grain and salt begot the commodities exchange in which Dolpo's pastoralists have been the lynchpin for hundreds of years.

The grain–salt exchange cycle of Dolpo involves more than just the shuttling of goods (Fisher 1987). Important social and economic relationships—especially that of the *netsang*—sustain these exchanges and are integral to Dolpo's cultural landscape. Literally translated as 'nesting place', *netsang* are business partners and fictitious family with whom one exchanges goods on favourable terms (Ramble 1997, personal communication). Most pastoralists in Dolpo have a *netsang* partner in each village their trade takes them to, a hearth and home for travellers in this exacting land. However, the bonds of these economic relationships were severely disrupted throughout the Himalaya by the closing of the Tibetan border in the early 1960's.

In the 1960's, communities throughout the Nepal Himalaya were barred entry into Tibet with their animals. During this period, the people of Dolpo simultaneously lost their traditional pasturage rights and access to their trade partners. Instead of being the geographical locus of the salt–grain trade, the people of Dolpo were forced to become its medium, travelling to Tibet with their animals for salt and returning south to the hill regions of Nepal to barter for grains.

Before this period, the pastoralists of Dolpo had Tibetan trading partners with whom they could negotiate for salt; these traditional commercial ties were severed. The Chinese government monopolised salt prices, taxed this commodity, and curtailed the dates that trade was allowed. The traditional autonomy of the Trans-Himalayan traders was thus usurped, jeopardising a local economy and culture. This story has been played out, in ongoing modulations and iterations, throughout the high Himalaya.

Since the advent of Chinese rule in Tibet, the nature of commerce across the Himalaya has radically changed. As China continues its rapid economic growth and minority regions like the Tibetan Autonomous Region are integrated into the national economy, the availability of industrially produced and commercially marketed wares is dramatically increasing. Today, goods produced in China's factories and urban centres routinely change hands in even the most remote outposts and nomad tents. Though western Tibet remains

desolate, barren, and expansive as ever, China's material culture is reaching even these remote corners. Networks once local are now regional and, increasingly, cash is substituted for traditional barter.

In some areas of Nepal, especially the Mt Everest area, the closing of Tibet's border coincided with the first ascent of the world's highest mountain and the beginnings of significant tourism in the Himalayan kingdom. A host of associated economic, social and educational opportunities arose and ethnic groups like the Sherpa used these to good advantage (Brower 1990). Areas like Dolpo, though, did not see such good times. Isolated and with few resources, these remote regions languished.

Even more than its reworking of trade patterns, the Chinese absorption of Tibet has had shattering and far-reaching impacts on seasonal pastoral movements in Dolpo. While trade deals in mobile assets, pastoralism relies on driving animals over fixed land-based resources—movements that have been worked out over many centuries. When the Chinese curtailed free movement across their political boundary, they shrunk the rangeland area available to Dolpo's herders and compromised the ecological underpinnings of a culture.

While the summer and autumnal movements of Dolpo's pastoralists have remained largely unchanged, present day winter migrations represent a radical shift in the patterns of an ancient culture. Before the 1960's, livestock from the four valleys of Dolpo were moved to the Tsangpo region of south-west Tibet for the duration of winter. The animals of Dolpo's pastoralists were given over to Tibetan nomads, who incorporated them into their herds. The nomads were paid in grain for the livestock they maintained, as well as the milk produced by these animals (Jest 1975). Both sides benefited from this arrangement: the nomads supplemented their food stores while Dolpo pastoralists were able to maintain larger herds year-round.

The people of Dolpo recall the 1960's bitterly. Their herds were decimated as the lack of winter pastures led to overstocking and massive starvation (Joshi 1982). The closing of the border eroded both the stability and profitability of Dolpo's pastoral economy. Faced with the inevitable starvation of their animals on a reduced resource base, the people of Dolpo sold hundreds of animals at crippling prices and permanently downgraded their production potential.

Knowing that they were constrained by climate, rangeland growth patterns, and available forage, as well as the continuing need for a salt market, the people of Dolpo negotiated a new arrangement with their Nepali *netsang*. Today, at the outset of winter, yak and *dzo* are moved to south-west Dolpa District and the people of Dolpo spend 6 months of winter in the homes of their Hindu business partners, who are from ethnic/caste groups like the Magar, Chhetri and Brahmin.

Herders from Dolpo consistently observed that range conditions in Kag-Rimi have declined since they first started coming to the area more than 30 years ago. A decisive factor in declining winter range conditions is the use of fire by the Hindus to promote fast and nutritive grass growth for their animals in spring. The Hindus' gain is logically the people of Dolpo's loss, as grasses charred in wintertime reduce the amount of forage available to the northerners' animals. The implication here is that different management techniques of cultural groups using the same resource may result in conflicts and declining resource quality.

The Hindu villagers also collect livestock fees per head from the people of Dolpo. While nominal, these grazing fees stack onto the expenses borne by the caravanners who transport salt. The yearly toll on their animals' health and productivity is high. Yet, the people of Dolpo are resigned to today's winter grazing constraints and must adopt a co-operative tone to maintain good relations with their hosts. They must simultaneously secure access to desperately needed winter range resources and still negotiate favourable terms of trade for their salt. Dependent as they are on the Hindus' range resources, the caravanners' sole bargaining chip and source of income—salt—is discounted.

As if China's absorption of Tibet were not enough, the increasing availability of alternative supplies of salt has also significantly disrupted the salt–grain trade. The slow but steady incursion of iodised Indian salt as a result of improved roads and other infrastructure have made this salt available to Nepal rural hill communities, with concomitant declines in the profits and demand for Tibetan salt. Traders from Dolpo unanimously noted an overall decline in the salt–grain exchange rate since the 1960's.

As roads and other means of modernity creep closer, economic loci shift, with inevitable dislocation for the people of Dolpo who previously thrived in the spaces between the worlds of Nepal and Tibet. Decentralised local networks of villages are being replaced by regional distribution and production centres. Anonymous bazaars and rural airstrips replaced traditional trade partnerships. For Dolpo's caravanners, a point of diminishing returns is being reached. How long will peddling salt be a viable economic activity? The present cultural and economic ordering, whereby Buddhist pastoralists from the northern mountains live for months in the villages of their Hindu *netsang*, is a resource use arrangement that is arguably unstable and bound to change. The once extensive trade network that the people of Dolpo relied on to barter their salt has evaporated and the changing terms of trade is undermining the long-term viability of these relationships. While the people of Dolpo continue to have an abiding interest in maintaining these economic relationships, that impetus is changing for the hill farmers.

Why, then, are there still good relations between the trading partners of Dolpo and Kag-Rimi, even though they are so different in ethnicity, values and economic gravitation? While salt from India is indeed cheaper than Tibetan salt, there are other hidden costs (Bauer 1997, unpublished notes). Supplies of government-subsidised commodities are finicky, usually delayed, and often expropriated by merchants better connected with government ration officers. A mere two kilos of salt is the maximum quantity available from the government at one time to households in Dolpa District. Tibetan salt, delivered in large quantities at one time, begins to compare favourably. Moreover, as one Hindu farmer insisted, 'The salt from the north tastes better and is good for our body, even if it is more expensive.'

Clearly, strict economic rationales do not wholly explain the persistence of the salt–grain exchange between the people of Dolpo and their *netsang*. Economic action is socially situated and cannot be explained by profit motives alone. Individuals act not only on behalf of their material interests but also to safeguard their social standing—that is, Dolpo's economy is embedded in a cultural system (Polanyi 1944; Granovetter and Swedberg 1992). Even in an increasingly capitalised system, economics are not the sole motivation for good relations between the *netsang* of Dolpo and Kag-Rimi. Generations of

netsang are joined by their common dependence on natural resources, and lives are shared between fragile surpluses and bartered goods. Observed closely, *netsang* partners also clearly like each other. One hill farmer explained:

We are friends, not just business partners. Benefit isn't always in terms of profits. After years of trading, our hearts agree. Though our religions, languages and customs are different, this is a long relationship.

Thus, the salt-grain trade, and the relationships upon which it is built, should not be prematurely declared dead: There is still a demand for Tibetan salt in the rural communities of western Nepal. Yet the likelihood that the economics of *netsang* relationships will continue to be rationalised on the basis of social or cultural traditions is questionable. While regional politics caused the attenuation of the trade, the Chinese and Nepali governments may still have a role to play in keeping these local distribution networks—these lifelines of rural subsistence—alive.

Instead, the resilience of Dolpo's pastoral system has been further undermined by government policies regarding resource management. In many parts of Nepal, with the encouragement of the government, community forest user groups have asserted control over their local resources—a process that is generally considered an unalloyed good. There can be unintended consequences of these rules, though.

In Nepal's middle hills, livestock find nutrition in and around forests; edge areas have experienced a mix of uses for centuries—from fuel harvesting, herb collecting, to timber felling and livestock grazing. When community forestry user groups assume exclusive power over these resources—backed by the state's forestry department—a traditional seasonal use may be jeopardised. Many communities' livestock herds depend on winter grazing pastures that lie outside the bounds of traditional clan or caste boundaries.

In western Nepal's Humla District, 80% of traders sold their animals when they were barred entry into winter pastures by local community forest user groups. Consequently, famine claimed almost 200 human lives in Humla in 1998 because the animals that had traditionally conveyed grains to the region were no longer arriving (Wagle and Pathak 1998).

The strength of transhumance—mobility—is here a weakness. Because range productivity is often low in the Himalaya, successful exploitation of these resources relies on being able to move between pastures. Without extensive rangeland resources, herding becomes uneconomical.

In 1984, the department of National Parks and Wildlife Conservation created Nepal's largest national park, Shey Phoksundo, in the Dolpo region. Since then, the department has suggested that local livestock numbers should be reduced to a prescribed carrying capacity (Sherpa 1992). These management policies are flawed and will place crippling restrictions on a pastoral production system that is already severely constrained. Applied as a rangeland management tool, carrying capacity would be inappropriate since Dolpo's is a non-equilibrium ecosystem in which climate, not grazing intensity, determine primary productivity. Moreover, department of National Park Planners have assumed a tragedy of the commons scenario for Dolpo when in fact social institutions exist that regulate resource exploitation within and between communities. For example, communal lotteries are held for the fair distribution of pastures and fines are levied for livestock encroachment on

agricultural land, to cite just a few examples. Finally, other government agencies have failed to support the pastoralists of Dolpo. The Department of Livestock Services has posted too few staff to the Dolpa District, and none of these personnel have experience with highland animals like yak. Thus, pastoral traditions that have already been subverted by radical geopolitical changes may be equally undermined by well-intentioned, but non-integrated, land use policies.

Closing remarks

Economic change has always been the cutting edge of cultural change (Fisher 1987). Today the people of Dolpo are subsumed in a regional economy that may soon have little place for them. The self-determination of a people who move with the seasons is no longer the exclusive domain of headmen and village councils as today's government bureaucracies and geopolitical claims also regulate it. The introduction of industrial goods has shifted both the tenor and terms of trade in Dolpo. Some traders have adapted and now peddle Chinese goods like clothes, thermoses, thread, watches, liquor, and other items in demand in the middle hills. Yet these trading patterns entail not only new goods but also a particular set of social relationships, with linguistic, religious, sartorial, culinary, and hierarchical symbols that are vastly different than the ones to which the people of Dolpo are accustomed (Fisher 1987). The two worlds may be too distinct to mesh—economics and identity may clash as the people of Dolpo struggle to redefine themselves. While adaptability is a hallmark of pastoralists, these changes are compounded in the span of a generation. The conjunction of geopolitical, cultural, and economic happenstance has placed epochal pressure on the culture and economy of Dolpo.

Dolpo's economy and culture are undergoing millennial transformations and the continuing viability of its pastoral way of life is in doubt. Prospects for increases in range productivity are limited, as are new areas for expansion. 'Today large numbers of pastoralists and livestock in Nepal must subsist on an ever-contracting land base, reduced by the closure of traditional rangelands in Tibet and restrictions on grazing in national parks' (Miller 1993). While the Trans-Himalayan pastoral system was always fraught with risks, it is increasingly difficult for the people of Dolpo to trade profitably in grain and salt, and they cling tenuously to a much diminished winter range. 'Even if Tibet were opened again, the system will not recover,' predicted one official at the Department of Livestock Services.

Some observers have wondered if, in the future, agropastoralists in Nepal's northern districts should choose to concentrate their economic activities solely on animal husbandry.¹ Since yields from agricultural fields are low, some advocate the production of hay on irrigated agricultural fields to improve animal nutrition and increase animal productivity. Yet in a pastoral system so tightly integrated with agriculture and trade, the plausibility of a full conversion seems low. Since winter fodder is the biggest constraint in Dolpo's pastoral production system, DROKPA—a US-based non-profit organisation—is

1. Blamont (1996), for example, noted a 10–50% decrease in the number of fields cultivated in upper Mustang District during the past ten years.

working with local resource user groups to increase fodder production by using solar pumps to irrigate fields of hay.²

Recounting his sojourn in Dolpo during the early 1960's, Snellgrove (1989) wrote, 'Except for a few adventurous spirits ... very few of them had been to the Nepal (Kathmandu) Valley'. That Dolpo is history. The few souls who stay in Dolpo for the winter may be called the adventurous spirits of today. Like so many other ethnic groups in Nepal, the people of Dolpo are increasingly migrating to urban centres amidst economic privation and declining yearly returns. Now, hundreds make the yearly exodus to Kathmandu during the cold season; some are even raising families there. Still, relative to other ethnic groups, few of the people from Dolpo have settled permanently in Nepal's capital.

Resettlement takes people from a setting in which they have the skills and resources to produce their own basic needs and transfers them to where these skills are of less avail (Gupta 1998). This may nullify a legacy of local pastoral knowledge and with it scores of functioning communities in a region that had been self-sufficient for centuries. Such knowledge is place-specific and relies on the collective memory of a locality, the archives of community intelligence. Wilson (1992) wrote, 'Extinction is the most obscure and local of all biological processes ... a fading echo in a far corner of the world ... genius unused'.

Optimistically, some Dolpo-pa will persevere by farming land and keeping animals, but others will divest their herds. 'In 20 years, people will live here only during the growing season. The wintertime's singing, drinking, weaving ... these will be gone', an old village lama predicted. Already there is a deep lacuna between those who once travelled with the herds to Tibet for the winter and a younger generation that aspires to different opportunities and lifestyles. Most shepherds now come from the ranks of the poorest households—hardly a group with the wherewithal to grow, if even maintain, Dolpo's pastoral economy.

The day-to-day, season-to-season harvesting of natural resources fuels pastoral societies like Dolpo's. It is these patterns that have radically changed for a people that bear a distinctive history, cultural sensibility, and way of life. The people of Dolpo face a watershed moment—a broaching of their ancient pastoral traditions, evolved over one thousand years. The future of a pastoral people remains in the balance.

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2. See <http://www.drokpa.org> for more information on this project.

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Yak pastoralism in Pakistan

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Summary

This paper provides information on the status of domesticated and wild yak in the northern areas and Chitral of Pakistan. Yak breeding is common in some parts of the northern highlands of Pakistan (i.e. Astore in Diamer district and Skardu and Ganche districts in Baltistan). The animal has great economic potential in this part of Pakistan and for this reason; their crossing with domestic cows has evolved, producing many different hybrid types. When male yak are crossed with cows, the male offspring, which are locally called *Zo*, are used as draft animals and are more resilient to lower altitudes than their yak parent. The female offspring, which are locally called *Zomo*, produce more milk than pure yak. The role of yak in the highlands of the northern areas of Pakistan is similar to that of camel in the deserts as a beast that provides pastoralists a means to survive during lean times and prosper during good.

Keywords: Feral, hybridisation, yak, *zo*, *zomo*

Introduction

There have been negligible efforts to document yak pastoralism in Pakistan, and very little is known about them. Thus, we may say that it is the domestic animal species, which has been the most neglected by researchers in Pakistan. The Karakoram Agricultural Research Institute for Northern Areas (KARINA) and the National Aridland Development and Research Institute (NADRI) have jointly initiated a field survey to document preliminary information on yak husbandry and its production system in the northern areas of Pakistan.

Yak pastoralism in Pakistan is confined to the higher altitudes of the northern areas and Chitral. The northern areas cover 72.5 thousand km² on Pakistan's north-eastern frontier with Afghanistan, China and India. It is one of the most mountainous regions in the world with more than half of the area lying at an altitude of 4500 metres above sea level (masl). In valley bottoms, temperatures range from 45°C in summer to 10°C in winter. Rainfall rarely exceeds 200 mm annually in areas below 3000 masl, but at higher altitudes, snowfall up to 2000 mm per annum are registered. Most of the mountain slopes are without vegetation.

Yak, the largest and heaviest of all Tibetan animals, belongs to the *Mammalia* class, the *Artiodactyla* order, the *Bovidae* family, the *Bos* genus and the *grunniens* species. The native name for wild yak is 'Dong' in Baltistan, 'Bapoo' in the Gilgit and Astore areas, and 'Terminy' in the Hunza, Nagar and Gojal areas.

Yak population and distribution

Cai and Wiener (1995) reported a total of 25 thousand yak and 0.1 million yak-cattle hybrids in northern Pakistan. However, Khan (1996) estimated that there were only 6000 yak in all of Pakistan. A recent census indicated that the total population of yak in Pakistan's northern areas was 14,914 head. Males accounted for 5603 of the total, among which 3752 were 3 years old and above, and 1851 were below 3 years of age. The female population totalled 9311, where 7015 were 3 years old and above, and 2295 were below 3 years of age. Skardu district has the highest yak population (7045 head), followed by Ghanche district (2532 head), Ghizer district (2355 head) and Gilgit district (1982 head) (Anon. 1998). No data is available for Diamer district, especially the Astore subdivision.

In Chitral, a total of 140 households keep yak, though the yak population of only 60 households has been reported (accounting for 484 head). Of these, 154 were adult males, 119 adult females and 211 young. Most of the yak population is found in the Broghol valley, 250 km north of Chitral city. The Broghol valley encompasses the villages of Broghol, Vedin Koch, Pechuch, Arguan, Chilma Rabat, Chikar Ishkarwaz, Garill and Laskhar Gaz. These villages are located at an altitude of 3387 masl.

Wild yak

There is no report or documentary evidence available confirming the existence of wild yak in Pakistan. Nevertheless, a herd of fifty feral yak, belonging to the Raja of Panyal, reportedly exist in the Sher Gilla water stream of Ghizer district.

Habitats

Domestic yak are most suited to elevations between 4000 and 5000 masl, where they forage throughout the year. Below 3000 masl, yak tend to loose vigour. Yak avoid broken ground, rocky places and glaciers, but are good swimmers. A newly-born calf can easily cross icy mountain streams by attaching firmly onto the tail of elder yak. They live in herds of 20 to 200 animals, including female yak and calves, though the average herd size ranges between 20 and 100 animals with only a few farmers having larger herds. Old male yak are solitary and sometimes live in herds of five. In early spring, herds increase in size and are found around grassy grounds, where they are attracted by newly sprouting grasses. With the advancement of the warm season, they move into the upper reaches until autumn. They return back to lower elevations in the valleys and water logged areas and wander for grasses in wastelands during winter.

Body weight

The body size of domestic yak is smaller than wild yak. The body weight of mature domestic yak ranges between 380 to 400 kg for males, and between 260 to 270 kg for females. Birth weights vary between 10 to 16 kg. Weight gain continues up to six months of age, at which time body weight ranges from 200 to 250 kg. The dressing percentage of male yak averages 44. Owing to its high haemoglobin and low fat content, yak meat is characterised by an intense red colour, and is devoid of marbling. It is coarse fibred but very suitable for sausages. Yak fat owing to its high carotene content (19 mg/kg of fat) is deep yellow in colour.

Yak breeding

A pure breed of yak is kept by herders in upper Hunza, of Gilgit district, as there is no tradition of cross breeding yak with local cows. This is also true in other subdivisions of Gilgit and Ghizer districts (e.g. the Nagar, Haramosh, Gupis, Phundar and Yasin valleys). Similarly, cross breeding is not practised in the Wakhan areas of Afghanistan, adjacent to Pakistan's Ashkoman valley. The vocabularies of the Bursho and Wakhi languages do not include any words for cross breeding and the pure breeds are known as '*Terminy*'.

Yak herders in Baltistan, however, do cross their breeding male and female yak with domestic cows and ox, a practice that has been going on since time immemorial. Hybridisation is more common in Shiger, Ghanche, and Hoshe in Baltistan, as it is in Ladakh to the east. It is also practised in Astore, Rattu and other areas of Diamer district, where one or two male yak are kept in each village for crossbreeding with local cows. These breeding males are highly valued by villagers and can go to any field for grazing. They are also fed special foods like butter and eggs, and are considered sacred. Their hybrid offspring have special local names and are used for specific purposes. Male hybrids are called *Zo* and the female *Zomo*. *Zo* make good draft animals and *Zomo* are considered the best producers of milk and butter. The feed requirements of hybrids are relatively low compared to cattle and are easy to keep even in the most unfavourable climatic conditions. Female yak, locally called 'Yakmo', are also crossed with ox. Their offspring are locally called 'Tul' (male) and 'Tulmo' (female), (Figure 1).

Yak health and hazards

In Chitral, Black Quarter has been reported as the major disease affecting yak, sometimes causing mortality as high as 15%. Haemorrhagic septicemia is another fatal disease. Foot and Mouth disease also has a high reported infection rate. The wolf is reportedly the main predator of yak, and acts as a major threat to the local yak population. In the northern areas, abortion, lung swelling and diseases related to poor nutrition and management also have been observed. There are no veterinary services available.

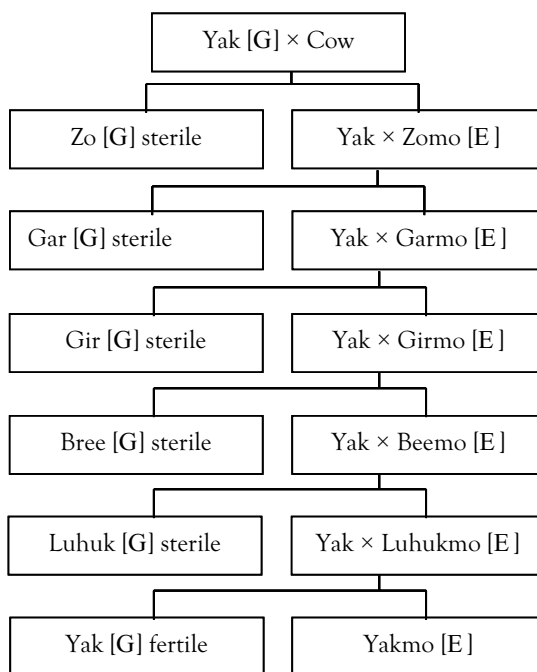


Figure 1. A commonly followed breeding scheme to produce hybrids of yak and cow.

Economic importance

The role of yak in the highlands is much the same as that of camel in the desert. A staff representative of the National Geographic Society, who was leading a Trans-Asiatic expedition to China along the traditional silk route remarked, 'Yak seem to do everything except lay eggs'. Yak are used for many purposes in the northern areas of Pakistan, namely meat, wool, leather and draft. Female yak make poor milking animals, and reportedly produce 1 to 2 litres of milk daily for 4 to 5 months. In eastern Pamir, the average milk yield during the peak lactation period of 150 to 170 days was estimated at 300 litres, in addition to 200 litres suckled by calves. However, Cai and Wiener (1995) reported the average milk production of yak in Pakistan at 600 litres per lactation of 200 days. Yak milk is a rich golden colour and has a high fat content, with fat globules of 4 to 5 micron in diameter. Solid non-fat content is also high. Butter made from yak milk has a typical aromatic flavour and does not turn rancid.

A wet hide constitutes approximately 8% of the live weight. Adult yak yield 750 to 1400 g of hair and 500 g down fibre per year. Hair is used for making tent covers, grain sacks and ropes. Down coats are made into felt. Tails are tied with a handle and utilised as dusting

brushes. Dried yak dung provides the most common fuel on the high plateaus of the northern areas of Pakistan.

In the northern areas of Pakistan, yak are considered excellent pack and riding animals for mountain travel. They are capable of carrying loads of up to 150 kg, and even with relatively poor feed, they can carry 50 to 75 kg loads for 13 to 16 hours a day for months. In difficult mountain terrain, yak are superior to mules in finding their way, and skilful in moving through snow.

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Grazing resources for yak production systems in Bhutan

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Summary

Bhutan has extensive grasslands, covering approximately 10% of the total land area. This resource is the base for the transhumance yak production system prevalent throughout the northern regions of the country. Although Bhutan has a relatively young research programme with limited resources allocated to the yak production system, a remarkable amount of information has been generated. This paper reviews information relating to grazing resources, especially that pertaining to the description of plant species and communities, production potential, resource management and quality monitoring.

Keywords: Bhutan, grazing resource, production system, yak

Introduction

Fodder resources

Fodder resources used in Bhutan vary with climate, farming system and season. It was estimated that the grazing of natural grassland (including fallow land), forest grazing, improved pasture, fodder trees and crop residues, would contribute to 38, 23, 9, 15 and 13%, respectively, of the fodder requirements for ruminants of Bhutan (Roder et al. 1998). Natural grassland above the tree line (alpine grazing land) is the main fodder resource for yak. During winter additional fodder is provided consisting of hay, crop by-products (including residues of alcohol making) and turnip.

Grassland species and ecology

The book *Flora of Bhutan* (in progress), especially the recent volume on the grass family (Noltie 2000), provides an important base for the description of grassland communities. Following a recent review, the dominant species in alpine grazing lands were identified as belonging to the genera: *Carex*, *Juncus*, *Agrostis*, *Festuca*, *Kobresia*, *Poa*, *Rhododendron*, *Potentilla*, *Primula* and *Danthonia* (Roder et al. 1998). Many authors tend to be subjective in their descriptions, influenced by seasonal trends in vegetation cover and by specific interests.

Grassland or rangeland specialists generally emphasise grass species (Miller 1987). Vegetation measurements made at altitudes ranging from 3100–4300 metres above sea level (masl), however, showed that broadleaf species provide the bulk of the vegetation cover (Table 1). With an increase in altitude sedges gradually replace grass species. A first attempt to delineate grassland types depending on elevation and precipitation was made by Tsuchida (1991). This classification can be used as a base for further refinement.

Table 1. Percent vegetation cover and composition for selected regions.¹

Region	Altitude (masl)*	Sites	Broadleaf (%)	Grasses (%)	Sedges (%)	Bare ground ² (%)
1. Laya	3800–4000	3	44 (41–47) ³	16 (12–23)	15 (9–22)	26 (17–35)
2. Laya	4100–4200	5	46 (20–70)	8 (1–19)	25 (15–35)	21 (6–38)
3. Lunana	4100–4800	4	41 (4–83)	15 (1–46)	30 (0–91)	15 (1–30)
4. Lhingshi	4400–4600	3	42 (12–72)	9 (7–12)	16 (6–30)	33 (5–75)
5. Domchen	4110–4300	4	61 (49–67)	8 (3–15)	29 (21–35)	1 (0–3)
6. Gorsum	3210–3360	3	45 (36–53)	25 (11–41)	14 (8–17)	15

1. Methods used were: Region 1–4, visual estimates from plots of 0.1 m² (Gyamthso 1996); Region 5 and 6, point method along line transects (Wangdi et al. 1999).

2. Including moss.

3. Values in bracket indicate range observed across sites for a particular region.

* masl = metre above sea level.

Grassland production

The country has over 400 thousand hectare of registered grazing land or *Tsadrog*. Registered as a specific land use class that cannot be diverted to other uses, these grazing lands belong only to the state and herders who have grazing rights.

To date, no reliable data on native grassland production under existing herders' or farmers' management are available. Several observers have estimated production based on one single visual observation, others have physically measured the dry matter production under total exclusion of grazing animals (Roder et al. 1998), Figure 1. Following these estimates the dry matter yields range from 0.7–3.0 t/ha for temperate grasslands at elevations <3000 masl and 0.3–3.5 t/ha for alpine grasslands at elevations >3000 masl. Estimates based on actual measurements are generally lower as compared to estimates based solely on visual assessments. With an increase in altitude the vegetative period declines. Figure 2 shows expected production using a simple model by extrapolating from maximum yields observed at 2700 masl and the growing days calculated based on the frost-free period. The work by Gyamthso (1996) confirmed that high dry matter yields are possible at elevations of 4000 masl.

Grassland management

Natural environment and the socio-economic setting in which they operate influence herding systems. Herders generally use sound management with rotational grazing.

Households with small herds often pool their animals together. Most herders have grazing rights for one or more pastures either individually or on a community basis. In some regions absentee landlords own large areas of grazing land. A unique system used for allotting communal pastures to herders was described for Ha district (Ura 1993). Grazing areas in the vicinity of permanent settlements at middle elevations (2000–3000 masl) are often used by cattle for summer grazing and by yak for winter grazing (Gyamthso 1996). It is not uncommon for two parties, such as a transhumant yak herder and a family from a nearby settlement, to have grazing rights for the same area.

Dry matter yield (t/ha)

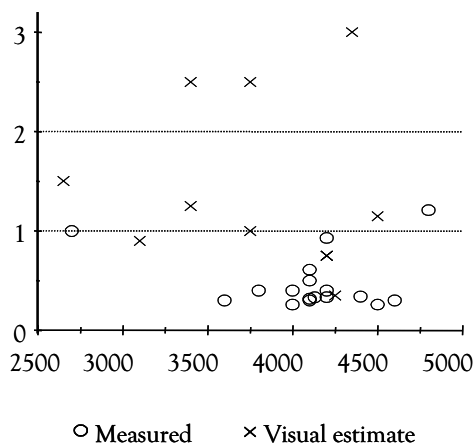


Figure 1. Existing grassland yields.

Dry matter yield (t/ha)

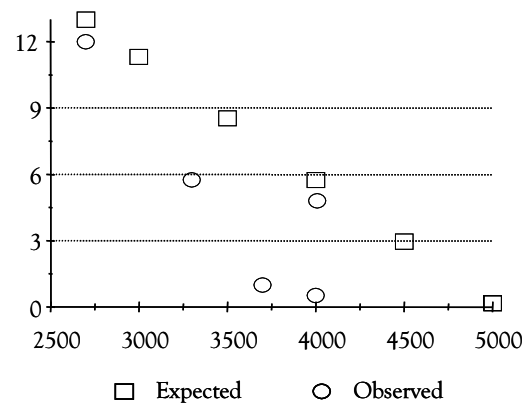


Figure 2. Potential grassland production.

Overgrazing is frequently mentioned as the main cause of low and/or deteriorating grassland yields, or a threat to the environment. No information is, however, available on livestock numbers and grazing pressure prior to 1960.

Forest and grassland communities include a large number of poisonous plant species such as *Aconitum* sp., *Senecio* sp., *Euphorbia* sp., *Pteridium* sp., *Eupatorium adenophorum* etc. (Roder et al. 1998). Animals generally do not graze these species except under abnormal circumstances such as lack of other feed sources, exhaustion (caused by long distance travel, heavy pack loads etc.), or other stressful situations.

Wildlife interactions

Grassland resources support a wide range of wild animals of which the takin (*Budorcus taxicolor*), the blue sheep (*Pseudovis nayaur*), the sambar (*Cervus unicolor*) and the musk deer (*Moschus chrysogaster*) are the most important. In recent years some of these species, especially the blue sheep, have increased, supposedly due to a decline in the population of its predators. Herders in the Laya region claimed that grazing resources have deteriorated due to an increase in blue sheep populations (Gyamthso 1996). Another wildlife species, which has substantially increased its population, is the wild boar.

Resource monitoring

A programme was initiated in 1997 with the objective of monitoring trends in species composition, biomass production, soil cover and soil quality (Wangdi et al. 1999). Under this programme, permanent observation plots have been installed in Domchen and Gorsum (Jakar), Soi-Yaksa (Thimphu) and Merak-Sakten (Trashigang). Individual observation plots, consisting of a circle with an area of 452 m² (r = 12 m), have been marked using a global positioning system (GPS) and iron pegs. Soil samples have been archived and the vegetation cover was recorded using points along a line transect. Vegetation changes will be documented through observations taken in 5-year intervals.

Potential for increased grassland production

Comparing the existing and the potential dry matter production, there appears to be substantial room for increased fodder production (Figures 1 and 2). Techniques such as control of unwanted shrubs, grazing management, introduction of legumes and P-application are available. The traditional use of fire to control unwanted shrubby species is presently illegal, but possible changes in the law allowing for controlled burning are under discussion. Combined effects of white clover introduction and P-application resulted in dry matter yield increases of 813, 317 and 64% for elevations of 2700, 3300 and 4020 masl, respectively (Roder et al. 1998). Most authors agree that increasing winter fodder availability and quality should be given priority. Lucerne, white clover, tall fescue, and cocksfoot and oat are the most promising species for this.

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Pastoral management and yak rearing in Manang's Nar–Phu valley

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Summary

The Nar–Phu valley is located in the Manang District of north-central Nepal. Physically rugged and harsh, its surface consists mainly of rock and ice. By far the greatest usable land resource in the valley is grazing land, and not surprising, animal husbandry is an integral part of the household economies of both Nar and Phu villages. Yak constitute the main livestock species and their products are either directly consumed or traded for cash or other goods that are not produced locally. Given that animal husbandry is one of the most important economic activities, each household spends a considerable amount of time on livestock either directly or indirectly. Those households with insufficient labour resources co-operate with others to pool their yak into one herd. Residents also employ pastoral management strategies, including seasonal transhumance, deferred grazing and rotational grazing, to maintain the productivity of their collective rangeland resources. In both Nar and Phu traditional, indigenous councils still function to set, administer and enforce rules and regulations pertaining to resource management and use. Though residents of Nar and Phu do actively manage their pastoral resources in such a way as to maintain the long-term viability of the pastoral sector, as attested to by the antiquity of the system in place, local people and others do see room for improvement and are amenable to upgrading their pastoral system to maximise the benefits that can be accrued. Features identified as areas for improvement include basic research, breeding, fodder production and management, damage by predators, market production, and economic diversification.

Keywords: Indigenous councils, labour organisation, Nepal, pastoral management strategies, transhumance patterns, yak

Introduction

Yak are raised all along the northern border region of Nepal, mainly between elevations of 3000 and 5000 metres above sea level (masl). Though yak productivity is often low compared to some livestock species, the animals are hardy and can thrive in the harsh and high altitude environments of the High Himalaya. They also efficiently convert locally available resources into useful products, which help sustain pastoral families by providing such things as food, fuel, draft power and cash revenue. This paper looks at pastoral

management and yak rearing in the Nar-Phu valley of Manang District. After positioning the local pastoral sector within the valley's larger environmental, social and economic framework, the paper focuses on the pastoral management systems of Nar and Phu. It begins by describing some of the features common to both places (such as labour organisation, pastoral management strategies, and traditional management institutions), and then details each village's annual transhumance pattern. The paper concludes by outlining areas for future research and development, as related to the local pastoral sectors of Nar and Phu.

Methodology

The study area was visited to get firsthand information on the yak rearing systems of Nar and Phu. Both formal and informal methods were used, including rapid rural assessment techniques. Interviews with key informants and focus groups were designed to elucidate issues related to the yak rearing system, including its prospects and problems. Discussions were also undertaken to find the best way to improve the system to benefit the local community as a whole. A checklist was used to guide the discussions, and information gathered was crosschecked with other villagers whenever possible.

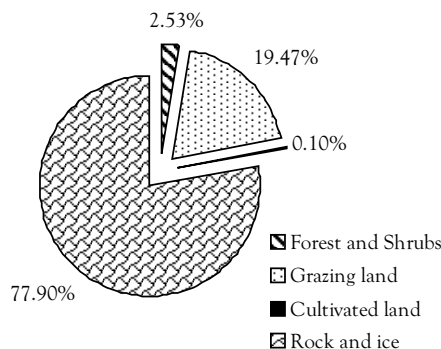
Background

The physical environment

The Nar-Phu Valley is located in north-central Nepal, in the heart of the main Himalayan zone. Lying between 84°E–84°30'E and 28°35'N–28°53'N, the valley is both geographically and politically remote. Administratively part of Manang District, it sits adjacent to the Tibetan Autonomous Region of the People's Republic of China, on the northern border of Nepal. Because of its politically sensitive location, the area has long been designated as a restricted zone by His Majesty's Government of Nepal, and is normally inaccessible to foreigners who can only go there with special permission. This fact, along with the physical difficulty of accessing the region during a significant part of the year, has stemmed the growth of tourism in the area, and kept it relatively isolated from the rest of the country.

The Nar-Phu valley is physically rugged and harsh. Its surface, which covers approximately 87,006 ha of land, consists mainly of rock and ice (Figure 1), which is of little use to local inhabitants. Forest cover is limited to less than 3% of the land surface, of which about 52% is temperate mixed forest, 14% conifer, and the rest bush. Cultivated land is extremely negligible, limited to only 0.1% of the total area. Of this, as much as 29% has been abandoned due to labour shortages, and/or insufficient irrigation and compost. For the most part, fields are normally found either on alluvial fans or along the sides of rivers.

By far the greatest usable land resource in the Nar-Phu valley is grazing land, which accounts for approximately 20% of the available land surface. Local inhabitants used grazing lands to raise livestock, mainly yak. All grazing lands are located above 3000 masl, though the majority (about 90%) lie above 4000 masl. Their high altitude and associated



Source: LRMP (1986).

Figure 1. Distribution of land resources in the Nar-Phu valley.

low temperatures means that the growing season is short and their overall productivity is limited.

The social environment

The two main villages in the valley, Nar and Phu, are located at approximately 4200 masl and 4000 masl, respectively, though villagers make use of lands as low as 3000 masl. Nar is the biggest village, harbouring 438 residents and 62 households. Phu is almost half this size, with only 180 residents and 36 households. Over the years, the population of both villages has declined due to the out-migration of people seeking better living conditions either in the district headquarters, Chame or the nation's capital, Kathmandu.

Culturally, the inhabitants of Nar and Phu share many affinities with other northern highlanders of Nepal, particularly those in Dolpo and the Limi region of Humla (von Furer-Haimendorf 1983). Like them, they practice Buddhism, rely heavily on animal husbandry (including yak), and are more culturally akin to their northern Tibetan neighbours than to Hindu lowlanders of Nepal. Linguistically, however, the people of Nar and Phu are more closely related to their Manang neighbours, though most people speak some Tibetan and a few men can read the classical Tibetan texts. According to von Furer-Haimendorf (1983), their language belongs to the same branch of the Tibeto-Burman family as Tamang, Gurung and Thakali.

The economic environment

The residents of Nar and Phu are economically versatile: animal husbandry, crop cultivation, herb collection and trade together constitute the basic life supporting activities of village residents. These four activities, which are fundamentally interrelated, are all complementary and none are practised on a full-time basis (Table 1).

Table 1. Nar and Phu villagers year-round time management.

Activity	Month of the year											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agriculture				←	←	←	←	←	←	←	←	←
Livestock	←	←	←	←	←	←	←	←	←	←	←	←
Herb collection							←	←	←	←		
Trading	←	←	←	←					←	←	←	←

← = Active involvement ←...→ = Passive involvement

Animal husbandry

Animal husbandry is an integral part of the household economy of both Nar and Phu, and every household raises livestock of one kind or another, including yak and yak-cattle crossbreeds, sheep, goats and horses. Yak constitutes the main livestock species, and owning them is considered a matter of prestige in the community (Richard et al. 1993). There is an estimated 1017 yak in Nar village, owned by a total of 43 households. These animals are divided into 22 herds, ranging from 15 to 90 head. Single households manage 11 (half) of the 22 herds, and 2 to 6 households jointly manage the rest. Phu village has an estimated 576 yak, which are owned by a total of 20 households. These are divided into 12 herds, ranging from 25 to 70 head. Of the 12 herds, single households manage 6 (half), and 2 to 3 households jointly manage 6 herds (Table 2).

The residents of Nar and Phu benefit from yak in many ways. Their products are either directly consumed, or traded for cash or other goods that cannot be produced locally. Animal products consumed locally include meat, milk and milk products, dung, wool and draft power. Meat, milk and milk products supplement the local diet and provide needed nutrients not readily available from other sources. Yak dung supplements fuel wood, and wool is used as the basic raw material for blankets and clothes woven and used locally. Draft power is necessary for both crop production and trade.

Trade items include animals themselves, milk products such as butter and *chhurpi* (a hard, dried cheese), and woollen products, particularly blankets (*pherpa*). A fully-grown yak (8–10 years old) sells for approximately NRs. 15,000¹ or higher, and a *chauri* for around NRs. 10,000. These are sold mainly to the people of Ngishyang, a neighbouring valley in Manang District. A *ser* of butter (approximately 1.32 kg) sells for NRs. 300, and a *pathi* of *chhurpi* (approximately 3 kg) for NRs. 180. In one season, a milking animal can produce approximately 10 kg of butter and 30 kg of *chhurpi*. Similarly, on average an adult yak produces about 2 kg of wool per year. Roughly 15 kg of raw wool (about 6 *dhamis*) are needed to prepare one blanket, which sells for somewhere between NRs. 800–900.

Sheep and goat are also economically important, especially during September–October at the time of *Dashain*,² when they are sold to buyers who come to the villages particularly for this purpose. Some people also keep cows for milk and/or horses for transportation.

1. Note that in August 2000, US\$ 1 ≈ 70 NRs.

2. *Dashain* is one of the main Hindu festivals in Nepal, at which time sheep and goat are in high demand, both as sacrificial offerings and for feasting purposes.

Table 2. Yak herds of Nar and Phu.

Herd ID no.	Nar village		Phu village	
	No. of contributing households	Total no. of yak	No. of contributing households	Total no. of yak
1	4	75	3	63
2	4	60	2	60
3	1	30	3	63
4	1	40	2	70
5	1	25	2	70
6	2	55	2	50
7	1	35	1	40
8	2	90	1	50
9	6	60	1	30
10	2	45	1	25
11	2	45	1	25
12	1	25	1	30
13	2	22	-	-
14	1	15	-	-
15	3	60	-	-
16	3	60	-	-
17	2	90	-	-
18	1	45	-	-
19	1	45	-	-
20	1	50	-	-
21	1	25	-	-
22	1	20	-	-
Total	43	1017	20	576

Agriculture

The main crops cultivated in Nar and Phu are naked barley and potato, supplemented by wheat and buckwheat on limited lands. Crop production in the valley is extremely limited and only possible from April to August. Only one crop a year is harvested and production, which is subsistence-based, is insufficient to meet the local food demand. The shortfall is met by bartering animal products and herbs for either wheat or buckwheat from Ngishyang and Gyasumdo (two adjacent regions of Manang), or imported rice from Lamjung (a neighbouring district).

Herb collection

Jimbu (*Allium* sp.) is a herb, which grows in the alpine region of the valley, where it is specially protected and managed by the local communities. It is typically collected during

August, and is considered an important trade item, particularly by the people of Phu. People from both Nar and Phu also collected juniper leaves during September–October, which are valued as incense. Both jimbu and juniper are dried and traded, mainly for rice during the winter trading period.

Trade

Winter (between November and March) is the main trading season for the residents of Nar and Phu. The main trade items are woollen and milk products, and aromatic herbs. These items are carried to sub-tropical regions of the country, where they are exchanged for either cash or kind. These, in turn, are used to purchase other items, which are also sold. This cycle continues so that throughout the winter months, money and goods are continuously revolving in a repeated process of business transaction. With the profits thus earned, individual traders cover their winter expenses and purchase household goods and food items used during the summer months back home.

Features of pastoral management in the Nar–Phu valley

The pastoral management systems of Nar and Phu are fairly similar, and several features are common to both villages. These include labour organisation, resource management strategies (e.g. seasonal transhumance, deferred grazing and rotational grazing), and traditional village councils responsible for resource management.

Labour organisation

Households in Nar and Phu manage their labour resources in such a way as to ensure that the four major economic activities (animal husbandry, crop agriculture, herb collection, and trade) are covered. Animal husbandry is one of the most important economic activities and each household spends a considerable amount of time on livestock either directly or indirectly.

Milking yak and calves require considerable labour input during the summer, as lactating females are milked daily and both they and their young are corralled at night. Male yak and non-milking females are much less time consuming, as they are left to graze freely on open pastures both in winter and summer. They usually only require the occasional eye from time to time to locate them and check on their well-being. Yak are not generally stall-fed, though under harsh winter conditions calves may be fed grasses collected for this purpose.³ Sheep and goats are closely tended throughout the year, as they are vulnerable to predators such as snow leopards. During summer they are taken to summer pasture but kept relatively close to the village area. Come the cold season they are moved down to the winter settlement area and fed dried grasses and agricultural by-products. Both in summer and winter they are kept inside pens at night. Horses are left free to roam in the summer pastures but kept corralled during winter. Like sheep and goats, they are fed dried grasses and agricultural by-products. Milking cows are tended like sheep and goat, but oxen are pastured like horses.

3. During particularly harsh winters, a number of yak usually die from starvation.

To utilise labour efficiently for pastoral activities, households with insufficient labour resources co-operate with extended family members, clan members or friends to pool their yak into one herd. Participating households then take turns tending the animals, and families with more animals tend the herd for a greater number of days (calculations are usually based on the proportion of milking females which each household contributes to the herd). The household responsible for the herd at any given time has the right to harvest all the milk produced during that period. In both Nar and Phu, the majority of households co-operate in this way, and exactly half of the herds are managed jointly. Of a total 34 yak herds in Nar and Phu, 17 (11 of Nar's 22 and 6 of Phu's 12) are made up of animals pooled from 2 to 6 households. Likewise, almost three-quarters of Nar households herd their animals jointly (32 of 43 households), and two-thirds of households from Phu (14 of 20 households) (Table 2). This mainly applies during the summer season, as animals are not generally milked nor actively herded during the winter months except to periodically locate them and/or rescue them in case of emergency. This is because most active family members are out of the village during this time, and children and old people are not well suited to herding and milking larger animals like yak.

Resource management strategies

The residents of Nar and Phu employ a number of pastoral management strategies to help them maintain the productivity of their rangeland resources at a level adequate to meet their long-term needs. Strategies used include seasonal transhumance, deferred grazing and rotational grazing.

Seasonal transhumance

Almost all yak-raising systems in Nepal involve some kind of migratory process, usually both vertical and horizontal. Animal movements are usually timed to accord with seasonal variations in climate, pasture conditions, and drinking water and labour availability. Like most of Nepal's highland pastoralists, herders from Nar and Phu practice a form of seasonal transhumance whereby animals are moved between winter (*Gunsa*) and summer (*Yarsa*) grazing areas. This strategy not only allows herders to increase their overall available grazing area, but it also reduces grazing pressure and minimises the threat of overgrazing in summer and winter pastures by allowing areas to regenerate during the time they are left ungrazed.

Unlike other areas in Nepal and elsewhere, however, there is not great altitudinal variation between the winter and summer pastures of Nar and Phu (approximately 3600 to 4200 masl). Instead, one of the main determining factors for classifying pasture as winter or summer is their accessibility. Generally speaking, summer pastures are inaccessible during the winter months due to unfavourable climatic conditions such as cold temperatures and heavy snows. Winter pastures, however, are usually accessible from the winter settlements, making it easier for herders to check on animals periodically. Throughout the winter yak may go to higher altitudes when there is little snow, but stay close to human settlements when precipitation is high.

In both Nar and Phu, people assign relatively more importance to their winter pastures than they do to the summer grazing areas. This is because winter pastures must provide forage to animals for the greater part of the year (approximately 7 months in Nar and longer in Phu) though they are smaller in area than summer grazing lands. In addition, winters are harsh, and most animal deaths occur during this time (caused mainly by starvation due to inadequate forage, natural catastrophes such as avalanches, or depredation by predators like the snow leopard). This is even truer of Phu, where the winter pastures are higher (mainly above 4000 masl) and used for a longer period of time.

Deferred grazing

The herders of both Nar and Phu practice a form of deferred grazing, and the movement of animals between summer and winter pasture areas is strictly regulated and co-ordinated with the agricultural calendar (von Furer-Haimendorf 1983). In both villages, animals are not brought down from the summer pastures until the crops and winter grasses have been harvested. After this, animals are allowed into crop fields to feed on crop residues for some time before being brought into the lower winter grazing lands. Those who do not adhere to the dates set by the community are penalised and fined according to a prescribed set of sanctions (see below).

Rotational grazing

To avoid overgrazing and to maintain forage productivity and range condition, herders from Nar and Phu rotate their animals from pasture to pasture, both in their summer and winter herding areas. This technique can actually increase forage production by as much as 40%; compared to those areas where rotational grazing is not practised (Alirol 1979). As in most grazing systems, actual rotation times vary depending on the quantity and quality of available forage, the number of animals utilising the pasture area, and the season of use (generally animals need to be rotated more frequently in winter, when forage is grown old, less nutritious, and less abundant than in the summer).

Traditional village councils in Nar and Phu

Prior to 1973 (before the introduction of government institutions in the Nar-Phu valley) the villages of Nar and Phu were governed by traditional, indigenous councils, which set, administered and enforced rules and regulations pertaining to community affairs. Today, though government and other formal and/or legal institutions have overtaken many of their functions and activities, these traditional councils are still active and very much alive. Though they operate informally and without government recognition or sanction, they continue to play a vital role at the village level.

These councils continue to regulate vital matters pertaining to resource management and use, among other things. For example, they determine the dates for livestock movements, crop harvesting, grass collection and herb collection, usually setting the dates

in close consultation with monastic leaders to determine the best time for executing activities according to the lunar calendar. The councils also see to it that these dates are respected, and enforce sanctions in the form of monetary fines when they are not. They collect annual animal and grain taxes from each household before the start of the winter migration, according to rates fixed long ago.⁴ The income received from taxes and fines is divided among the council members as a form of remuneration for their services on the council. Since membership on the council is rotated annually and all households take a turn, the system is considered fair and is accepted by the community at large. The council is also expected to use the funds to host an annual feast in November, in honour of the formal Village Development Committee. At this time, a goat is usually slaughtered and the next year's council members appointed.

The councils, called *Ghampa-Ngerpa* and *Gamba-Lhenjing*⁵ in Nar and Phu, respectively, are made up of two types of members: decision-makers (called *ghamba* in both Nar and Phu) and decision implementers (called *chow* in Nar and *Lenjing* in Phu). Both, however, are involved in all activities. All household heads have to hold both types of posts at least once in their lifetime. Membership is rotational, and eligibility is based on residence (villagers only), age (15 to 60 years old), sex (men only), and marital status (married men only). Residents above 60 years of age are waived from active membership, and unmarried men are not included.

In Nar, the council has 7 members altogether (4 decision-makers and 3 decision implementers), whereas Phu only has 5 (3 and 2, respectively). Council members come from different clans,⁶ and community rivalries are based more on clan affiliation than on political ideology. Since one Nar clan has more member households than the others, that clan has to hold two *ghamba* posts. In Phu, because there are only 2 *Lenjing* posts, these are rotated between the clans annually.

Once the crops are harvested and the livestock are moved to the winter pastures, the duties of the existing council are fulfilled. They then hand-over their positions to the new council members, who will take up their responsibilities immediately after the winter migration is complete.

Patterns of transhumance in Nar and Phu

Nar

In Nar, no animals (including yak) are allowed to come down into the village and/or winter pastures between the first week of June and the first week of September. There are two

4. In both Nar and Phu, the amount of tax per animal is determined by age. In Nar village, the amount is fixed at NRs. 0.125 for yak less than 1 year old, NRs. 0.25 for those 2–3 years old, and NRs. 0.50 for those 4 years and above. In Phu, where the rate was fixed more recently than Nar, the amounts for animals 1, 2 and 3 years old and over are NRs. 1, 2 and 3, respectively.

5. Gurung (1977) calls this council *Dhaapaa Shabaa*.

6. There are three major clans in each village: Nar Phobe, Tonden Phobe and Yoba Phobe in Nar, and Ngochoy, Wong Chhongdang and Laten in Phu. 'Phobe' means family or clan in the local dialect. Note that the Yoba Phobe mentioned here is listed as 'Er or Ewa' by von Furer-Haimendorf (1983), 'Bandilama' by Gurung (1977), and 'Ewa' by Richard et al. (1993). These writers also subdivide Tonden Phobe into 'Tonden' and 'Menden', but villagers consider them as part of the same clan.

barriers in Nar: a long stonewall just below the village and the other being the Nar River. If any animal crosses these lines during the summer, the owner of that animal is fined. If the first barrier is crossed, the fine is NRs. 5.00 per animal irrespective of the species. If the second line is crossed, the fine is NRs. 10.00. If the owner does not willingly pay or argues the case, the fine may go higher. The traditional village council is responsible for enforcing these rules and collecting fines.

As the summer agricultural season draws to an end in Nar, villagers begin to collect all the grasses from around their fields prior to the actual crop harvest. The main grass species collected is *Pennisetum flaccidum*, known locally as *ramchhi*, though other herbaceous plants are also collected. In August, the crops are harvested. As soon as the crops are harvested (usually by the last week of August), and their vegetative portions such as roots, stems, leaves, threshed out residues etc. are stored for the winter, livestock, including yak, are brought from Lepche (where the summer pastures are located) to graze. This movement usually takes place in the first week of September.

After grazing for about 15 days on leftover plants and crop residues around the village, yak are again moved back to the closest summer pastures—Jambu and Chubche⁷—for a short time. Yak are not taken to the interior parts of the summer pastures at this time, both because they will have to move out again shortly, and because snow is due at any time and it is difficult to evacuate the animals after it comes. Dung collection is also easier closer to the village. During the short grazing of yak in these sites, the villagers finish harvesting their crops and grass in the winter settlements of Meta, Jhunam and Chyaku. When the harvest is complete and the grains and grasses have been stored, yak are moved into the winter pastures, usually in the second week of October.

In Nar, both yak and pastures are divided into two groups for winter grazing. The winter pastures are divided between an area called Namya, and that, which includes the pastures surrounding Meta, Jhunam and Chyaku. Of the two groups of yak, one group goes to Namya and the other remains near the winter settlements. Namya is said to have very good pasture, and indeed supports almost twice as many herds as the other sites combined (14 of 22), and almost twice as many animals (640 head went to Namya during the 1999/2000 winter season, as opposed to 377 which went to Meta, Jhunam and Chyaku). Namya is relatively inaccessible during the winter,⁸ and as male yak are required throughout the winter season for occasional transportation, they are not taken to this site. Instead, only females, which are not used for transportation, are taken to Namya during the winter.⁹ The herds that go to Namya are not permitted to stay more than a day at Meta on their way.

As the winter season draws to a close, the group of yak from Meta, Jhunam and Chyaku are also moved to Namya, where they join the rest of the village herds. This is generally in the 4th week of April. All the yak of Nar village then stay together in Namya for about a month, usually until the end of May.

7. Jambu and Chubche are situated to the west and north of Nar village, respectively.

8. Before moving animals to Namya, villagers observe a ritual well-wishing the yak and asking that they be safeguarded against predators and/or other calamities. Once there, they will not be regularly tended.

9. There are some exceptions to this rule. Households with weak animals can ask permission to join the Namya group, and will most likely receive it if the request is considered justified. Likewise, the same is true if too many yak are thought to be stationed in the other winter herding stations. Richard et al. (1993) also mentioned that use rights in these pastures could, under some conditions, be bought and sold.

Within the first week of June, all yak from Namya are moved to Meta, then to the village and ultimately on to the summer pastures of the Lepche valley. Since by this time all crops have been sown, yak will not stay either in Meta, the village, or any other stations en route for more than one night. Within the second week of June, the animals are required to reach the summer pasture area. Should any herd be delayed, the owner(s) will be fined. This rule is strictly followed, as overstaying in the winter pastures means that grass needed for the following winter is jeopardised.

From June to October, until the yak are again moved down to the winter pastures, all the yak of Nar village remain inside the Lepche valley. The herds are moved from one site to another depending upon the availability of grass at any given location. They start grazing from the bottom of the valley and proceed into the higher regions gradually over the season, coming down again as the climate gets colder and as they prepare for the winter migration. Once in the summer pastures, males and some non-milking females are separated from the milking animals and calves, and driven to higher pastures. The lactating females and calves remain in the bottom of the valley or at lower stations, where tending and milking are easier for the herders. This division of the herd helps to balance the use of available grass, given the limited growing season and pasture area.

Phu

Like Nar, the pastures of Phu are divided into summer and winter grazing areas. The summer pastures are Lhonga, Ghurusangma, Kulung, Ngaru and Pangre, and the winter pastures are Ghyo, Gungale and Namjunge. Within each major pasture area there are several sub-areas where yak are moved within a given period of time. Lhonga, Ghurusangma, Kulung and parts of Ngaru are used throughout the summer, whereas parts of Ngaru and Pangre are used only after jimbu (*Allium* sp.) is collected in the second week of August.

In Phu, yak are not permitted into the village or the summer pasture areas before the first week of May. They may remain in the higher elevation sites of the winter pastures for another month, however, as long as they reach the summer pastures by the first week of June. Like Nar, any infraction of this rule is subject to a fine, administered and enforced by the traditional community council. In Phu, the fine is NRs. 5.00 per animal, and again like in Nar, if the offender tries to avoid payment the amount may increase (in the past some people are said to have paid as much as NRs. 2000). Also like Nar, yak are not allowed back down into the village and/or winter pastures until the crops have been harvested in accord with the date set by the community. After the crops are in, yak are moved from Ngaru and Pangre to fields close to the village in the first week of September, where they graze on crop residues for about 10–15 days. They are then moved back to Ngaru and Pangre, where they remain until the end of November.

In last week of November, yak are moved down to the winter pastures. Unlike Nar, Phu does not distinguish between the winter pastures, nor are yak divided into separate groups for winter grazing. Instead, Phu residents can move their yak herds to any winter pasture they choose. As noted above, throughout the winter yak are rotated between pastures according to the prevailing weather, forage and predator conditions.

Conclusions and recommendations

It is obvious that residents of Nar and Phu actively manage their pastoral resources, and the antiquity of their system attests to the fact that they have been doing so in such a way as to ensure the long-term viability of the system as a whole. However, both local people and others do see room for further improvement, and are amenable to upgrading their pastoral system to maximise the benefits that can be accrued, and ensure the continued productivity of the pastoral sector. Because grazing land and livestock movements are still managed by local traditional councils in Nar and Phu villages, and the communities trusted these councils to keep the system functioning effectively, any improvement activities in yak rearing in this region should utilise and build on this local social organisation.

Outlined below are some features of the pastoral system, which have been identified as areas for improvement.

Basic research

A systematic assessment of the contemporary pastoral systems of Nar and Phu is needed. Milk yields,¹⁰ wool yields and growth rates of yak should be recorded under different conditions and seasons. Data is also required to assess the number of animals, which die (for various reasons) and/or are sold each year.

Breeding

The physical isolation of both Nar and Phu due to the rugged and mountainous terrain on all sides of the valley severely limits the size of the breeding population of both villages, which do not have access to even each other's bulls. It is not currently known to what extent this has affected inbreeding in the yak population, or even whether this is a problem. Research needs to be carried out to both document the local yak breeds, and to assess the genetic and reproductive viability of the population.

Though local people do selectively breed their animals to a small extent,¹¹ crossbreeding local herds with relatively productive breeds from outside the region could be promoted to improve the productivity of yak in Nar and Phu. To facilitate this, local herders would need to be trained in animal breeding.

10. On average a Chouri gives 2.5 manas of milk per day, so that one chouri yields approximately 254 litres of milk per season (1 mana \approx 0.57 litres, and 2.5 manas \approx 1.43 litres). They are milked only in summer (June–October) once a day. The informant survey revealed that about 144 Chouris (approximately 25% of the herd) are milked each summer in Nar and Phu villages. This gives a rough estimate of the potential value of animal products, although not all milk is sold for cash or bartered for commodities.

11. Like in many other yak-rearing areas of Nepal (e.g. Langtang and Dolpo), every year an uncastrated bull (Chheddar), selected for its superior physical traits such as sturdy body structure, white wool, fleshy body etc. is offered to the gods on behalf of the whole community. These bulls are then protected by the community, and are free to roam freely throughout the pastures without danger of being slaughtered or used for labour. Because they roam freely and can follow the rest of the animals wherever they are moved, they effectively function as breeding bulls for the herds.

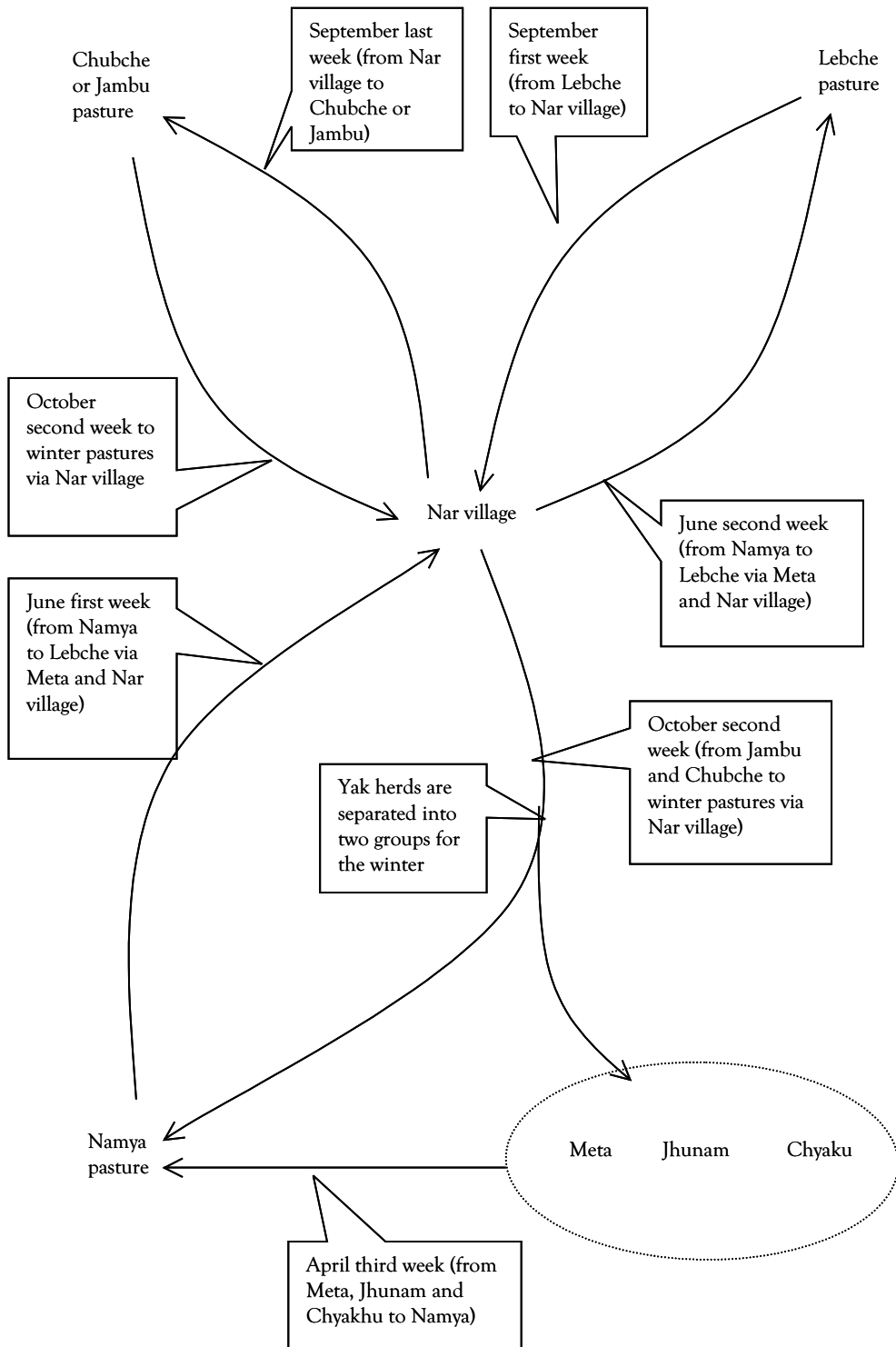


Figure 2. Transhumance pattern of yak in Nar village.

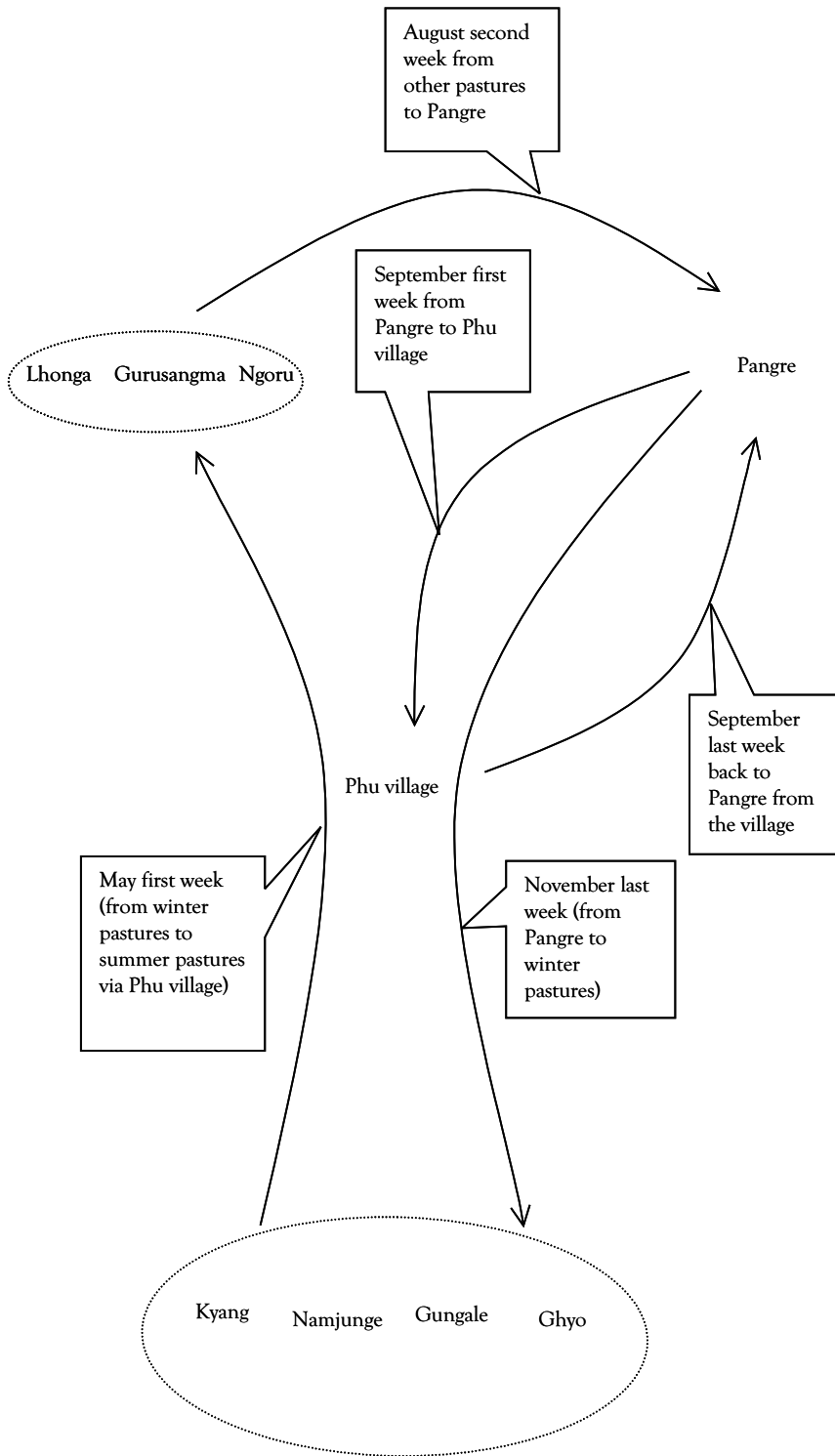


Figure 3. Transhumance pattern of yak in Phu village.

Fodder production and management

Currently, the local people do not feed hay to yak in winter, despite the fact that yak are the principal livestock species; one of the mainstays of the economy, and starvation during winter is one of the main causes of animal loss. There are several reasons for this:

1. Yak are left free to roam throughout the winter, and reaching them when snowfall is heavy is difficult.
2. Hay is not sufficient for all livestock which require winter fodder.
3. Residents think of yak as hardy animals that can survive in the harsh winter environment.

To minimise the number of animals lost in winter due to starvation, grass should be cultivated to use as fodder in the winter months. Richard et al. (1993) recommended some suitable grass species such as *Elymus nutans* (wild rye grass) and *Medicago falcata* (alfalfa). Such grasses can be grown on the corners of fields. Potential sites for growing grasses are the winter settlement sites of Chyaku, Jhunam and Meta (Nar village) and Kyang (Phu village). These sites were once cultivated with crops but have since been abandoned because of lack of labour, irrigation water and declining soil fertility. Irrigation facilities should be revived at these sites and grasses, which can be grown on low fertility soils, should be promoted. The mistake made by the government's Northern Pasture Development Project in the 1980s, which tried to promote ecologically unsuitable exotic species of fodder, should be avoided at all cost.

Damage by predators

The local population considers depredation of livestock by snow leopards a problem. Because the snow leopard has no alternative habitat, programmes should be developed to minimise the conflict between domestic yak and the wild cat and promote the co-existence of both populations. Experiences from the adjoining Ngishyang valley suggest that avoiding core areas (e.g. those areas close to dens or which overlap the territories of more than one leopard) help reduce the incidence of destruction. Herders should also be made aware of the need to cautiously watch animals grazed at these sites or on rough and bushy terrain. A detailed study is required to understand the depredation phenomenon, and to develop a depredation management programme.

Market production

Yak products are currently processed and marketed using traditional methods and techniques. The quality of products can be upgraded to fetch a higher market price, especially milk products such as butter and *chhurpi*, which can be sold at the nearby tourist market in Ngishyang. Herders and other community members need to be trained appropriately to develop the necessary skills and techniques needed to tap this market.

A considerable quantity of dried yak meat is shipped to Kathmandu from Nar and Phu every year. This is sold mainly to Manang people residing in Kathmandu, but there is a larger

market for such meat in Nepal, which is currently not being tapped. Hygienically dried and packed yak meat could also be promoted to add value to this product. In addition to the blankets already being produced, high quality woollen shawls could be produced out of fine yak wool, which can fetch a higher market price than the present products. Souvenir products can also be produced from coarse wool.

Economic diversification

Promoting activities other than traditional ones could diversify the economic base of this area. Opening the area to controlled tourism could be one such activity. However, the impacts of tourism should be cautiously managed by controlling the number of tourists into the area, and by making both tourists and locals aware of the negative and positive aspects of the tourism industry. Tourism should ideally be managed so that it is integrated into the whole economic system, to ensure that it does not conflict with traditional socio-economic activities.

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A probe into the pastoral production system in Hongyuan, eastern Qinghai–Tibetan Plateau

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Summary

This paper describes the pastoral production system and its problems in Hongyuan County, eastern Qinghai–Tibet Plateau. Three different pastoral production systems existed in 3 periods: the traditional period (up to 1958), the collective period (1958–1983), and the privatisation period (from 1983 onwards). Duration, facts and figures, the management system, tenure and tax, and gender-based labour division for each period are discussed. It has been indicated that.

1. Settlement is an inevitable trend of development, but livestock mobility is still required so that nomads do not feel increasingly marginalised and neglected by global progress;
2. Since rangeland was divided among individual households and fenced, nomads now have a stronger feeling of ownership than before, which usually leads to better rangeland management and reduces conflicts among people;
3. Livestock and rangeland management during the privatisation period raised new problems for nomads, including questions relating to optimal herd size and rotation on family pastures. To reduce tax amounts, nomads are unwilling to tell census representatives how many livestock they actually have, which prohibits decision-makers from acquiring accurate information pertaining to rangeland use, and as a result, far inadequate preventive medicine against some infectious diseases are ordered. Winter pastures of some households are overgrazed;
4. Gender-based labour division in pastoral areas is more obvious than in any other area of China. Women perform most productive and reproductive activities, but men are the household decision-makers. The gender gap has widened since the fencing of rangeland because men have more leisure time and are even tending to transfer their traditional duties to women.

Keywords: Gender, pastoral production system, Qinghai–Tibet Plateau

Introduction

Located between 75°–103°E and 25°–37°N, the Qinghai–Tibet Plateau occupies 143 administrative counties (cities) of the Tibetan Autonomous Region, Qinghai, Gansu,

Sichuan and Yunnan Provinces. The plateau has a total area of about 2 million km², which makes up about 21% of the country's territory. Owing to high altitude and related harsh environment, crop cultivation is not practical in most areas of the plateau, and livestock grazing offers the most feasible land use for hardy animal breeds such as those of yak and Tibetan sheep tolerant to the cold. Animal husbandry is the representative economic mainstay throughout the plateau, which has supported Tibetan nomadic pastoralists for thousands of years. The output value of animal husbandry approached 35.03% of the Gross Agricultural Output Value (GAOV) of the plateau in 1990, which was only 2.01% of the state GOAV in the same year (Su and Huang 1996). The area is vast and isolated in a very low economics, while the environment on the plateau has deteriorated. Nomads, at the same time, are feeling marginalised and neglected by global progress. The search for an optimal alpine socio-ecosystem requires that the production system and problems existing in pastoral Qinghai–Tibetan Plateau must be well understood. This paper is based on the authors' long-term working experience and recent intensive investigation in Hongyuan County (in Aba Tibetan and Qiang Autonomous Prefecture, Sichuan Province) of the eastern Qinghai–Tibet Plateau.

Major production systems

Traditional period

Duration, facts and figures

The traditional pastoral production system existed in Hongyuan until the Democratic Reform in 1958. With low population and livestock density, the traditional system had been able to retain its mobility and flexibility in adapting to the harsh environment, and no major changes occurred in the system for thousands of years. The total number of livestock in Hongyuan in 1959 was 130,120, among which 76.68% were yak, 7.03% horse and 15.98% sheep (Editing Committee 1996). The average survival rate of young livestock was about 50%, and it was not uncommon for all the livestock of a household to die in a natural disaster. Yak cow, the base to maintain herders' life, consisted the majority of smaller herds.

Management system

The tribal leader had unique decision-making privileges pertaining to rangeland use. Pastures were reallocated to subtribes every year in the spring based on subtribes' subordinating relationship with the tribe, and had little to do with the number of livestock. At the same time, the tribal leader also determined the grazing routes when rangeland was reallocated. Usually livestock would be moved to the summer pastures in late April and returned to winter pastures in late October. As a rule, the tribal leader's livestock would be moved ahead of the others, anybody else violating the rule would be fined. Specially assigned guards protected the private pastures, and free access was prohibited. In most cases,

5–6 movements in the summer pasture took place every year, and collective rites were performed for safety when returning to the winter area.

Tenure and tax

All of the rangeland in Hongyuan belonged to different tribes and the tribal areas had distinctive natural boundaries. Tribes were regional organisations, which functioned on the basis of blood relationship. Pastures within a tribe were used in common, except those areas owned by tribal leaders, pasture-lords and monasteries. Individuals held access rights and were obliged to protect the common pasture of the tribe. All livestock were privately owned, with about one-fifth of the households possessing enough livestock to meet their household consumption needs after being taxed. Tax was taken from adult milking yak cow only and the amount for each was about 1 kg butter/year. Most pastoral households in Hongyuan owned some livestock but not enough to maintain them and so they had to rent additional yak from pasture-lords or monasteries for survival. The rental for each yak cow was about 12 kg butter/year (about 60% of the total production). Other households survived by being hired by tribal leaders, pasture-lords and monasteries. All employees maintained their personal freedom and could pasture their salaried livestock, if any, together with their employers' herds.

Gender-based labour division

Gender-based labour division was obviously formed in the long pastoral history. Men were the household heads and dealt with important family affairs. They were responsible for grazing, transporting pack animals, moving tents and fighting. Women's main tasks were milking, cooking, butter churning, fuel collecting, wool spinning and weaving.

Collective period

Duration, facts and figures

The collective period lasted in Hongyuan for 25 years, from 1958 to 1983. Two types of collective production were set up during the Democratic Reform in 1958. One was 'Mutual Aid Artel' (1958–1973) followed by 'People's Commune' (1973–1983), and another was the State-Owned Farm. Production units were artel and farm of 'Mutual Aid Artel' and State-Owned Farm, respectively, whereas 'People's Commune' had two levels of production units as commune and brigade (under commune). All local people were forced to turn over their livestock and most of their property to the collective by shares. About 72.74%, 20.70% and 6.55% of Hongyuan's total 143,508 livestock in 1960 belonged to artel, state farms, and individual households, respectively. Livestock numbers kept increasing during this period and reached 486,500 by 1983 (Editing Committee 1996).

Management system

Livestock owned by collectives were usually divided into different groups, like milking cows and their calves, young yak (2–3 years old), bulls, non-milking cows, castrated and ready to offtake yak, breeding animals etc. Labour forces on the farm or artel were accordingly divided into different groups, each having its own target livestock group. The leadership group of a production unit decided the division of tasks and grazing routes.

Tenure and tax

Most livestock and pasture during the collective period belonged to the state or the collective. The collective owned all the means of production, and people accomplished their assigned tasks to earn work-points. Payment was given to individual households once a year according to the share and total work-points of family members.

Gender-based labour division

From the 1950s to the 1970s, women in China were highly encouraged to do the same activities done by men. In pastoral Hongyuan, however, traditionally formed gender division of tasks still existed during this period. Five or six women and one man formed one grazing group, and were responsible for about 100 milking cows and their calves. Women in the group were responsible for milking, butter churning, and calf herding, whereas the man herded the cows. Three to four men formed a grazing group for non-milking cows. The rest of the men and unmarried girls (women would not be assigned into a grazing group until they were married) were assigned tasks like guarding artificial grassland, cutting grass, collecting herbal medicine, and so on.

Privatisation period

Duration, facts and figures

Since 1983, the privatised pastoral production system in Hongyuan is still seeking a way to achieve sustainable development. All livestock owned by collectives were equally distributed to individual households according to the number of family members regardless of their age and sex. The introduction of household livestock contracts stimulated pastoral productivity greatly, but most households tried to raise as many livestock on common pasture as they could. In 1995, as one of the 25 selected pastoral demonstration counties, ‘Integrated Socio-Economic Development’ was initiated in Hongyuan. Rangeland was divided among individual households or household groups (from 10–20 households). Each household was required to build a house, an animal shed, and a hay storage barn as well.

Management system

Herders no longer need to work together in groups as they used to in past decades. About 40% of nomad households have settled down in one plot of pasture all year round, while the remaining 60% have one plot of winter pasture near the township or village office and share one faraway large plot of summer pasture with others in the household group. Each household can decide its own livestock number and composition, as well as when and where to graze within its pasture holding. Most households herd their livestock from November to next June on their winter pasture and keep moving on summer pasture from July to the end of October. Some households who have only two plots of pasture take non-milking cows to their summer pastures, while a few without much livestock are reluctant to move to their summer pasture at all, regardless of the time of a year.

Tenure and tax

Herders have to sell at least 1.25 kg meat/yak per year to the county slaughterhouse, pay 2.0 RMB Yuan/yak per year (US\$ 1 = 8.2 RMB Yuan during this survey) and 1.5 RMB Yuan/hectare per year to the collective after livestock and rangeland are ranches to individual households. Rangeland tenure of state farms still belongs to the state. The tax for livestock contracted to individual households on state farms is: 12.5 kg milk and 2.25 kg meat/cattle per year; 0.5 kg meat and 0.35 kg wool/sheep per year. Certain herd increasing rate on state farm is also required.

Gender-based labour division

Because most of the winter pasture and some of the summer pasture of individual households are fenced, many men were freed from their traditional grazing duty. Now men have more leisure time and are more involved in commercial activities than before, whereas women are still busy with milking, collecting yak dung, making butter and even grazing. The daily working hour of most pastoral women in Hongyuan exceeds 16 hours.

Issues identified

Settlement

The settlement of nomads does not mean that livestock grazing occurs in small areas all the time. Most nomads stay at their winter house during the long winter, but arrange to herd their livestock in different parts of their pasture on a rotational basis, whether or not they have joint or separated pastures. Without exception, nomads in Hongyuan set up their tents and move 3–6 times during the summer. Some nomads are even thinking of fencing their pastures into small plots for rotation every 7–10 days. In that way, they say, pasture can be used most effectively and in such a way that damage is minimised.

The settlement of nomads is undoubtedly an inevitable trend of development, though it seems impractical at the present time to let nomads settle down completely as some officials

suggested. Nomads' own perspectives as developing partners should be considered and strengthened by researchers and decision makers. It will be very hard for nomads to have access to public services like medicine, education and markets, if they do not settle down. Settlement of nomads, local officials say, can also help to seek gender equality and equity through policy and training courses to both men and women, otherwise women have little chance to access. It is also difficult to improve infrastructures, like roads, electricity, water and shelter, without settled dwelling places.

Land tenure

Most pastures in Hongyuan have been divided among individual households or household groups (state farm pasture and parts of the summer pasture) with leasehold of 50 years. A 30 m wide land (pasture) along the main road, 5 m wide migration routes, some water resource areas and unusable rangelands have been left for common use. Many households have their own pastures fenced and have made them inaccessible to others' livestock. Pasture use between households is regulated by renting, at the rate of 30 RMB Yuan/ha per year for common natural pasture. Some nomads rent other's pasture to protect or fallow their own even though they have enough pasture for their livestock. Very few pasture hosts care how many or how long livestock graze on their pasture within a year. Since rangeland was divided among individual households, nomads now have a stronger feeling of ownership than before, which usually leads to better management.

Most pastures divided among household groups are not fenced yet. The household group determines the grazing schedule and migration routes. The decision as to where each household will set up tent in the common pasture is made through discussion or drawing lots. The livestock of each household group can graze freely within the boundary, which is usually unseen by outsiders. However, when livestock graze in other administrative pasture, conflicts, including quarrels, fights, and theft of livestock, frequently occur. The fencing of pasture actually considerably reduced such conflicts.

Livestock and pasture management

The total number of livestock in Hongyuan was 486,500 in 1983, but the number dropped to 387,000 in 1999—16 years after livestock had been contracted to individual households (Editing Committee 1996). County governors and professionals estimated that the real number of livestock in Hongyuan in 1999 was approximately double the statistical number. In most cases, for tax reasons, the nomads are unwilling to tell census representatives how many livestock they actually have. This not only prohibits decision makers from getting accurate information on rangeland use, but also creates other problems. For example, far inadequate preventive medicine for some infectious diseases are ordered and distributed every year by the county animal husbandry bureau because of inaccurate statistical data. Keeping a large herd of livestock is actually an effective way to compensate for the low productivity of individual livestock in the harsh environment. In recent years, nomads tend to sell more male yak than they did before in order to maintain an optimal herd size. Proper livestock improvement should be considered to ameliorate livestock quality and limit

overall quantity. Livestock mortality was high when grazing within fenced pastures was first introduced, but now it has been reduced considerably.

Generally speaking, rich families with more livestock were reluctant to accept rangeland division before it was carried out. However, of over 30 interviewees, no one complained about fencing pasture for individual households after it was conducted. Nomads have their own indigenous knowledge about sustainable rangeland use. Most of them are thinking about sustainable use of their own pasture while they simultaneously try to develop and maximise livestock numbers by drawing on techniques such as fallow periods, rotational grazing, grass cultivation, fertilising, weed extermination, hay storage, and the sale of livestock. Though we cannot parry to say some households keeping their herds on winter pasture near main road year round to easily sale milk during summer, which lead to rangeland degradation. As for weed extermination, nomads consider that edible grasses still make up a high ratio on the hills but weeds have increased on the plain and in the valley area. They are encouraged to use herbicides to exterminate weeds, but more scientific research should be conducted on the ecological effects of this practice.

Gender

Gender-based labour division in pastoral areas is more obvious than in any other area of China. Men do not milk animals, weave, dry yak dung, cook or collect water. Once, in 1995, the Hongyuan county governor refused a strong request from the Vice Director of All China Women's Federation to pose for the media in a milking posture because he thought he would lose prestige among his people. Women's strenuous hard work often exceeds 16 hours a day, and in some cases even reaches 21 hours a day. Women carry milk to milk stations to sell every day, but it is men who collect the money from the station at the end of the year. Men mostly control other commercial activities like selling the variety of livestock products and buying things. Men are considered the household head and decision-makers in pastoral families.

After the rangeland was divided among individual households and fenced, the labour of both men and women was reduced but the gender gap widened. Men's traditional task was to graze animals, but now they only need to take livestock out every morning and then drive them back every evening within the fenced pastures, as watching livestock all day long is no longer required. More leisure time has made it possible for men to go to the city and benefit from entertainment activities outside. So, even grazing is now becoming women's work.

Acknowledgements

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Nomadism: A socio-ecological mode of culture

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Summary

The paper presents the concept of *nomadism* as a socio-ecological mode of culture as developed by Scholz (1995) in his landmark work throughout the Old World Dry Belt of northern Africa, and across western and central Asia. He defines *nomadism* as a region-specific, temporally and spatially ubiquitous survival strategy that was based on subsistence and coexisted as an alternative to the sedentary cultures of agricultural and urban societies. The disruptive changes that have taken place in the life of nomads will be described and perspectives for a sustainable development of their environment, the drylands of the Old World, will be given.

Keywords: Old World Dry Belt, pastoral nomadism

Introduction

Land degradation and ecosystem decline in drylands have prompted major changes in global perceptions of land use in these regions. Consequently, such perceptions found their expression in the formulation of the UN Convention to Combat Desertification. These drylands are mainly distributed in the great arid belt of the Old World, commonly referred to as the 'Old World Dry Belt', which stretches from Mauritania in western Africa to Mongolia in Central Asia, which FAO (1993) classified 91% of its surface as potential rangeland (Figure 1).

Apart from scattered and locally concentrated oasis farming, this region has been traditionally used by pastoral nomads. In a generally inhospitable physical environment, pastoral nomads have developed a very complex system of using rangeland resources and maintaining grazing capacity of these barren lands to survive. Increasingly, however, pastoralists find themselves confronted with expanding insecurities in a rapidly changing world, caught between a mobile past and a sedentary future. In the ensuing discussion, I will briefly introduce the concept of *nomadism* formulated by Scholz (1995).¹ Pastoral nomadism is seen as a 'socio-ecological mode of culture' and is seen as the only way to guarantee a sustainable livelihood that exploits the extensive but seasonal grassland of the steppes and

1. Scholz is professor of geographical sciences at the Centre for Development Studies, Free University of Berlin, Germany. His concept has emerged after years of intensive studies on nomadism in different regions of the Old World Dry Belt.



Source: Scholz (1995).

Figure 1. *Distribution of nomadism in the world.*

the mountains of this region.² I will then describe the two aspects of the concept—the ‘thesis of origin’ and the ‘thesis of decline’, then sketch the present situation of nomadism, and finally present future scenarios for nomadism in the future.

Nomadism as a socio-ecological mode of culture

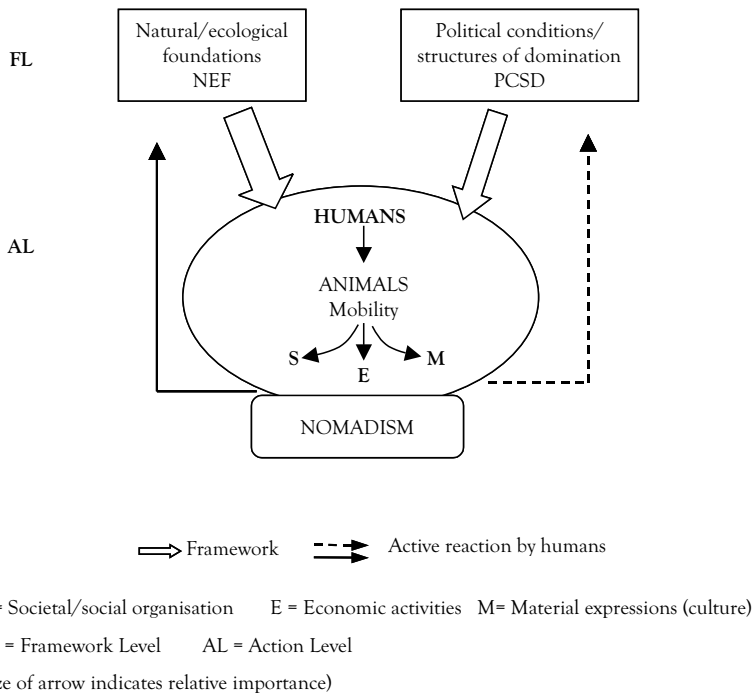
With the domestication of wild graziers of the Old World Dry Belt, pastoral nomadism has been the dominant livelihood throughout most of the region’s history. Nomadism is a strategy to optimise use of available natural resources and capitalise on socio-political conditions. While often ridiculed as primitive or even ‘incomplete’ by outsiders,³ it is in fact a highly sophisticated adaptation for exploiting energy captured in the grasslands of the region. Livestock most effectively harvest the limited vegetation that humans cannot eat, and can harvest it over large distances. Livestock thus was and still is the central and functional link between human necessity and the social and physical environment. The specific characteristics of livestock, in turn, contribute decisively to the diversity of nomadism in the region. For example, yak survive better at high altitudes than lowland

2. It should be noted that nomadism (no permanent home) and pastoralism (primarily relying on livestock for subsistence) are not synonymous. There are nomads who are not pastoral (such as hunters) and pastoralists who are not nomadic (such as modern dairy farmers). In this paper the term nomadism is used synonymously with pastoral nomadism.

3. One author (cited in Scholz 1995, p.25) described nomadism ‘to some extent as an incomplete adaptation to a certain natural environment’.

bovines and arid regions favour camels compared to horses. In addition, the compositions of herds reflect both ecological variables and cultural preferences.⁴

It was mobility that was the very essence of herding. Pastoral nomads in the Old World Dry Belt, whether in the savannahs of Africa, the steppes of central Asia or the high altitude pastures of the Qinghai-Tibetan Plateau, have always needed to move their animals regularly to make use of the spatial and temporal patchiness of grassland resources. Nomadism was therefore more than just an ecological adaptation or an adaptation to the political environment. It was a ‘region-specific, temporally and spatially ubiquitous survival strategy, an independent *socio-ecological mode of culture*’ (Figure 2) which was based on subsistence and coexisted as an alternative to the sedentary cultures of agricultural and urban societies (Scholz 1995).



Source: Scholz (1995).

Figure 2. Model of the ontological theory of nomadism as a socio-economic mode of culture.

The thesis of origin and of decline

On the basis of ideas, viewpoints and findings of economic and social history, and of anthropological archaeology, Scholz (1995) comes to the conclusion that, given a certain regionally specific, ecological and socio-political setting, nomadism as a strategy developed repeatedly in new and original forms, in a variety of settings. In the vast literature on the topic, changes between a sedentary lifestyle and a nomadic lifestyle are often described. The

4. Mongolian nomadism is just one example where an important symbolic value attaches to horses.

reasons for the rise of one and the decline of another were mainly economic or political crises. To mention just one example, for the Turks of southern Kazakhstan, it was common for a nomad to settle down and farm after loss of livestock, and a rich farmer to buy livestock and again shift to nomadism (Scholz 1995, p.49).

Despite the fact that nomadism is the optimal means to utilise the ecologically fragile dryland ecosystem, it is the socio-political environment that often changes the extent to which nomadic people maintain such a lifestyle. These changes are not only a mere consequence of colonial policies, socialist collectivist campaigns or the power-seeking attempts of a nation-state, but also the result of subtle and complex, social and economic, direct and indirect processes, occurring at different levels of society. Since the beginning of the 19th century the constitutive framework for pastoral nomadism has undergone major structural changes so that pastoral nomadism seems likely to disappear completely, especially in light of recent rapid modernisation.

The present situation

Steps toward settlement and enclosures, which have been widespread throughout the Old World Dry Belt in the 20th century, have prompted nothing short of a ‘topomorphic revolution’⁵ across the vast grasslands. That is, rangeland privatisation and parcelling has dramatically restructured local nomadic space and reshaped the socio-ecological environment. The enclosure of pastures that were traditionally held in common exacerbates widespread problems of land degradation and desertification of the physical environment, and has led to new problems in the social environment by broadening the disparities in economic wealth among nomadic households and communities (Figure 3).

The aim of such rangeland policies was basically to make traditional pastoral land use more efficient through overcoming the ‘tragedy of the commons’ the term coined by Hardin (1968), and to create an intensive livestock production regime for commercial purposes, characterised by fencing, irrigated forage production, stall feeding, improved breeding, machinery, chemical fertilisers and marketing.

The once dominant experience of mobility has significantly changed to a more settled version of pastoralism. The traditional nomads of the Old World Dry Belt have made obvious adjustments in their traditional lifestyle. Mud-brick houses have replaced tents and yurts, cultivated fields have come to cut across pastureland, and vast barren spaces traditionally used by nomads are now abandoned. Contemporary herders of the region now essentially move the grass to the animals. The traditional system has therefore given way to a new type of spatial mobility, highly restricted and dictated by access to markets and amenities, lacking little similarity to the distant migrations of old. As evidence has clearly demonstrated, these new forms of spatial mobility contribute decisively to the above-described changes in the physical and social environment. In many countries,

5. Walter (1988, p. 23) introduced the term ‘topomorphic revolution’ to describe a ‘radical shift of topistic structure, a fundamental change in the form of dwelling together... [that] conceals, interrupts, or breaks the old forms, causing new structures by patterns of exclusion, enclosure or dissociation.’

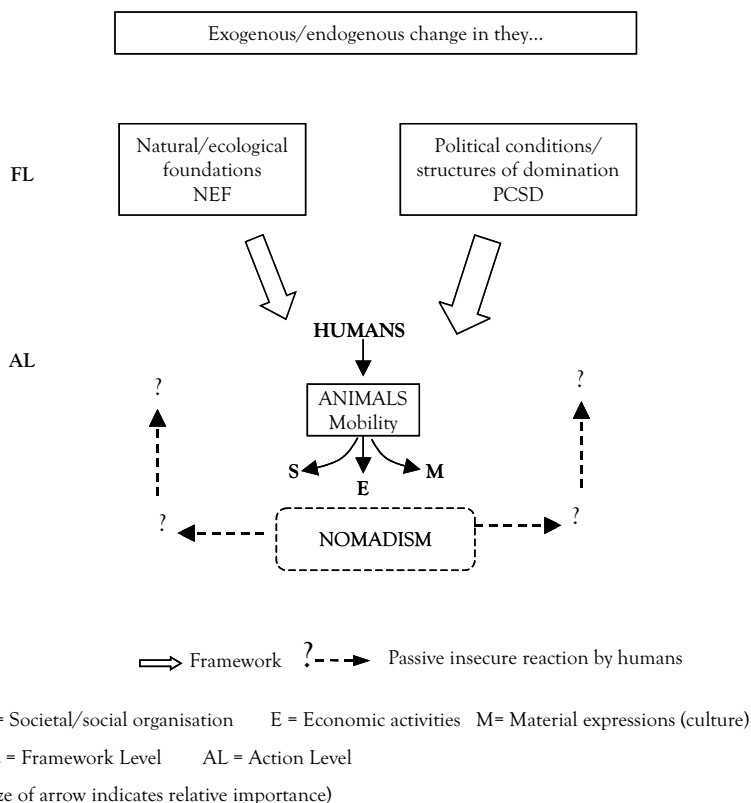


Figure 3. Model of the change of nomadism as a socio-ecological mode of culture.

indigenous knowledge has been disrupted and households have abandoned once effective grazing strategies (Williams 1996).

Future perspectives

A pessimist could easily take the view that the decline of nomadism is irreversible. However, for development planners this would of course be equal to abandoning any hope of dealing with the issue. Therefore it is our duty to maintain a small amount of optimism. This optimism becomes even more important when one keeps in mind that the majority of the countries of the Old World Dry Belt are among the poorest of the world. In addition, the natural resource base is declining rapidly worldwide while population pressures on the overall available agricultural and pastoral land are increasing. Some questions come to mind. For example, what is happening with the vast barren grasslands of the Old World Dry Belt formerly used by nomads? Under the changed conditions described above, what possibilities exist to make economic use of them? What are the preconditions for sustainable pastoral management of the drylands?

To answer these questions fully is too extensive a task to be dealt with here. To date, there is still a lack of successfully implemented strategies in these dry land environments.

However, on the basis of traditional modes of appropriate use (such as the informal institutions of the *hema* in Saudi Arabia) and bearing in mind the negative impacts of primarily market-oriented development projects, Scholz proposes a modern form of mobile livestock-keeping as the solution (Scholz 1995). To guarantee its success, some preconditions have to be acknowledged by policy-makers and planners alike. Priority has to be given to subsistence rather than market-oriented production, to job security rather than increases in productivity, and to resource conservation rather than increasing yields.

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Economics of yak farming with relation to tourism in Nepal

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Summary

Traditional yak farming in Nepal is declining at an alarming rate, characterised by a measured shift from traditional butter and hard cheese (*Chhurpi*) to modern Swedish style hard cheese, yak steak and as pack animals for tourism. Also there has been a positive shift in number of animals/herd due to economic reasons such as economic return per herd and per animal. It has been noticed that small herds (15 heads) show positive but very low gross margins compared to that of economically viable sized herds (55 heads). The economic return of a household running a hotel business in a yak raising area is five times higher than that of a household with an average herd size of 55 animals. However, yak, as a pack animal in the tourism sector, is essential to carry the loads of tourists in the Himalayan region of Nepal. Without yak and their crosses, it is impossible to strengthen the growing tourism industry in this remote and rugged terrain. In addition to this, the meat value of yak steak in these areas is another major reason closely associated with tourism development. To develop tourism in Nepal, there is an urgent need to readdress policies that affect yak husbandry for the mutual benefit of farmers as well as for rural-urban migration and employment. A slow transition policy has been prescribed in this paper to resolve the current issues related with yak husbandry and need for tourism.

Keywords: economy, Nepal, tourism, yak farming

Introduction

Yak husbandry is one of the important and indispensable aspects of the Sherpa's life in the high altitude rangelands of Nepal. Currently, about 56,488 yak and yak-cattle hybrids are present in Nepal and are distributed in the highlands of the 14 northern districts. Yak population in Nepal is declining (about 200 thousand yak and hybrids in 1961) at an alarming rate (Paudel 1993) due to lower economic benefits derived from yak husbandry. In addition, the more educated youth of the Sherpa community is unwilling to remain in traditional yak husbandry because of more lucrative opportunities in the trekking industry. Yak is one of a few domesticated animals that can survive in a cold and low oxygen environment that result in a low input feeding system. They have strong limbs, small solid

hooves with hard edges and a narrow hoof fork that make them ideal for carrying heavy loads to supply both local and tourism demands in the rugged and snowy terrains of the Himalayas (Cai and Wiener 1995). As there is no suitable substitute animal for carrying such loads, yak and its hybrids remain an indispensable part of the trekking industry above 2500 metres above sea level (masl) (Joshi et al. 1994).

An attempt has been made in this study to highlight the usefulness of yak in the Himalayan rangeland of Nepal with special reference to the socio-economic relationship of the Sherpa community with tourism and yak husbandry. The constraints and potentials of yak husbandry in Nepal have also been identified and relevant policy implications have been suggested.

Materials and methods

The author visited Manang, Mustang, Solukhumbu and Rasuwa Districts of Nepal and interviewed yak farmers of Chame (Manang), Muktinath (Mustang), Tyangboche, Junubeshi villages and the government yak farm, Syangboche, in Solukhumbu district, and Chandanbari and Chilime villages of Rasuwa districts. Different types of participatory rural appraisal (PRA) tools were used to extract relevant data for this study. Other relevant data were collected from published and unpublished sources. Thus collected data were grouped into two categories of different herd sizes for comparative performance analyses. The major limitation of this study is data deficiency. Hence, this paper should be considered as a case study rather than a detailed survey.

Tourism and yak population

There are about 56,488 heads of yak and its hybrids in the country distributed over 14 Himalayan districts in the kingdom (Table 1). The highest yak population is present in Solukhumbu District, followed by Dolpa, Mustang, Rasuwa, Manang, Dolakha and Taplejung. The population distribution of yak and its hybrids in various districts of Nepal is directly related with the relative importance of the tourism sector in these areas. It is quite obvious to note that Mount Everest area attracts more high paying tourists than other trekking routes of Nepal. Hence, the yak population is the highest in Mount Everest trekking area compared to other trekking areas (Dolpa, Mustang, Manang, Helambu and Langtang). During 1996, the total trekking permits issued by the National Authority of Nepal were 6752, 4944, 15,562 and 1728 for Everest, the Helambu and Langtang areas, Annapurna (Manang, Mustang) and other trekking routes, respectively (NRAN 1999). The yak and its hybrid population and flow of tourists clearly show a positive correlation both in terms of pack animal needs and its products such as raw milk and hard cheese for consumption by tourists.

Economics of yak husbandry

The following assumptions were made for the estimation of the gross margins of two prevailing yak herd sizes that are commonly observed in Nepal.

- Breeding males are left open for free grazing on communal pasture land, therefore, bear no cost of rearing;
- Four calves under 1 year (about less than 60 kg body weight) is equal to one adult animal;
- Two steers/bull is equal to one adult animal;
- Milking animals are fed 2 kg of good quality hay and 1 kg of potato or grain per day during the winter period of about 120 days;
- Draft animals are fed 3 kg of hay per day during two tourist seasons which last for about 150 days;
- All animals are fed either 1 kg of grain or locally grown potato during winter months of housing;
- Food transportation cost for herdsman/herdswomen for two sizes of herd in alpine pasture are 30 and 60 persondays;
- 20% of adult animals are culled for meat every year.

Table 1. *Yak and hybrids population in Nepal.*

District/village	No. of population
Taplejung	4036
Shankhuwasabha	3024
Solukhumbu	12,059
Sindhupalchowk	321
Ramechhap	1229
Dolakha	4470
Rasuwa	5027
Gorkha	3641
Manang	4709
Mustang	5037
Dolpa	6605
Mugu	2250
Humla	2029
Jumla	2051
Total	56,488

Source: DLSO (1999).

In a herd of 15 (A) adult animals the percentage composition of the gross income is highest from meat sale; followed by pack load income, milk sale, *Chirpa* (undercoat) sale and *Pu* (hair) sale (Table 2). On the variable cost structure side, the percentage composition of hay feeding cost/year (milking), hay feeding cost/year (draft), hay feeding cost/year (dry), grain/potato feeding (milking), herdsman cost/year and food transportation cost/year are estimated to be 16, 30, 11, 18, 24 and 1.8%, respectively. The gross income from meat sale is

the highest because of the popularity of yak steak among tourists. The gross return from pack animals arising from tourism (meat and pack animal value) is the biggest monetary attraction for the Sherpa community to rear yak. When these yak are culled, they become valuable as yak steak. Both meat and pack animal commodities are major incentives for modern yak husbandry in Nepal. Without the tourism source of income generated by yak husbandry, the positive but very low gross margin (Nepalese Rupee (NR) 30,825 of small herd size A), clearly signifies that traditional yak husbandry for milk and butter is no longer a profitable and sustainable enterprise, especially among the younger Sherpa population.¹

Table 2. Gross margin estimation of a herd of 15 adult animals (5 lactating cows, 5 dry cows, 5 castrated males and 4 calves).

A	Gross income	Unit	Yield/animal	Nos.	Rate	Amount NR ¹	Share (%)
	Milk sale (180 days lactation)	litre	225	5	30	33,750	9.07
	Chirpa sale/year	kg	1.5	15	250	5625	1.51
	Pu sale/year	kg	1.2	15	150	2700	0.73
	Meat sale/year	kg	150	3	400	180,000	48.38
	Off-farm income as load/year	day	150	5	200	150,000	40.31
	Total					372,075	100.00
B	Variable cost	Unit	Concentrates	Nos.	Rate	Amount	Share (%)
	Hay feeding cost/year (milking)	kg	240	5	45	54,000	15.82
	Hay feeding cost/year (draft)	kg	450	5	45	101,250	29.67
	Hay feeding cost/year (dry)	kg	160	5	45	36,000	10.55
	Grain/potato feeding (milking)	kg	120	15	35	63,000	18.46
	Herdsmen cost/year	day	270	2	150	81,000	23.74
	Food transportation cost	day	30	1	200	6000	1.76
	Total					341,250	100.00
C	Gross margin (A - B)					30,825	

1. US\$ 1 = 73 Nepalese Rupee (NR) in September 2000.

In the herd of 55 (B) adult animals, the percentage composition of the gross income is once again the highest from meat sale (55%), followed by pack load income (34%), milk sale (7.8%), *Chirpa* sale (1.6%) and *Pu* sale (0.8%). On the variable cost structure side, the percentage composition of hay feeding cost/year for milking *Nak* (female yak), hay feeding cost/year for pack yak, hay feeding cost/year for dry *Nak*, grain or potato winter feeding for milking *Nak*, herdsmen cost/year and food transportation cost for herdsmen are estimated to be 17, 32, 12, 25, 13 and 1.3%, respectively (Table 3).

The gross income from meat sale is even higher in herd B than herd A because of the larger herd size (Joshi 1982). In addition to this, the gross return from pack animals used for trekking is the biggest monetary incentive to raise yak for the Sherpa community. After culling these yak are also valuable for local consumption. Both of these economic activities (meat and transportation) are the major incentives for modern yak husbandry associated with tourism in Nepal. However, the positive gross margin (NR 363,525) of herd B clearly signifies that the large share of income from meat and pack yak generated by tourism sector

1 US\$ 1 = 73 Nepalese Rupee (NR) in September 2000.

Table 3. Gross margin estimation of the herd of 55 adult animals (15 lactating cows, 15 dry cows, 15 castrated and 10 steers along with 12 calves).

A	Gross income	Unit	Yield/animal	Nos.	Rate	Amount NR	Share (%)
	Milk sale (180 days lactation)	litre	225	15	30	101,250	7.78
	Chirpa sale/year	kg	1.5	55	250	20,625	1.58
	Pu sale/year	kg	1.2	55	150	9900	0.76
	Meat sale/year	kg	150	12	400	720,000	55.31
	Off-farm income as load/year	day	150	15	200	450,000	34.57
	Total					1,301,775	100.00
B	Variable cost		Concentrates	Nos.	Rate	Amount	Share (%)
	Hay feeding cost/year (milking)	kg	240	15	45	162,000	17.27
	Hay feeding cost/year (draft)	kg	450	15	45	303,750	32.37
	Hay feeding cost/year (dry)	kg	160	15	45	108,000	11.51
	Grain/potato feeding (milking)	kg	120	55	35	231,000	24.62
	Herdsmen cost/year	day	270	3	150	121,500	12.95
	Food transportation cost	day	30	2	200	12,000	1.28
	Total					938,250	100.00
C	Gross margin (A - B)					363,525	

(NR 1.17 million) outweighs the income generated by traditional yak husbandry for milk, hard cheese and butter. Therefore, traditional yak husbandry is not a profitable enterprise.

The income generated from hotel operations and pack animals associated with the trekking business along the most popular trekking routes of Nepal is about five times higher than that of traditional yak husbandry in Nepal, all in the short period of about five months in a year. Without yak as pack and meat animals, there is a remote chance that the growing demand for food and transportation need for tourism and trekking sector in Nepal can thrive in the future.

Despite the lucrative incentives from yak husbandry of larger herd sizes, younger people in Sherpa are attracted toward more rewarding means of making money such as working as guides and porters for trekking and mountaineering expeditions. These people are aware of the hardship of yak husbandry in remote and inaccessible areas and the low return on investment as compared to the hotel and trekking businesses. For this reason and the cheap availability and accessibility of Tibetan yak, they prefer instead to import them as pack animals. This along with the high labour cost in the mountain region is major setback for traditional yak husbandry in Nepal. Therefore, there is an urgent need to find incentives to support traditional yak husbandry in Nepal.

Problems of yak husbandry

The major problems of the yak husbandry are:

- inadequacy of hay during winter months
- absence of loan disbursement programme for increasing the herd size to achieve economics of scale and efficiency

- lack of infrastructure such as roads and electricity for marketing high value yak cheese
- lack of an efficient yak breeding programme to maintain the genetic diversity
- absence of mobile cheese processing suitable for the transhumance system of yak husbandry as being done in other countries and
- closure of alpine pasture access in Tibet for Nepalese yak herders.

Solutions

So far as solutions to the above mentioned problems are concerned, the following policy prescriptions are suggested:

- Alpine pasture restoration programme, sustainable yak stocking rate along with control grazing scheme based on people's participation should be launched in the focused areas;
- To achieve economics of scale and efficiency in yak husbandry, subsidised credit facilities should be strengthened to the interested yak herders;
- Subsidised solar panel generated electricity should be availed to the migratory herds for better quality cheese production and cow dung saving for revitalising alpine pasture for optimal growth which, otherwise, would be used for cooking and heating;
- Separate government yak breeding station should be established for at least two pure lines for yak and one pure line for *Chauri* (fertile female) and *Jhopka* (infertile male) production to meet the immediate milk and pack animal needs along lower altitude trekking routes;
- Given the yak's ability to survive in harsh conditions and the people's ability to sustainably derive livelihood from it (Khan 1995), indigenous livestock management systems should be strengthened;
- Research and development on yak husbandry should be accomplished in the light of Nepalese perspective so that conservation of yak through sustainable utilisation could be achieved in the near future.

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The economic comparison on yak production in two types of cold season grassland in Tianzhu, China

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Summary

In cold season (winter and spring) grassland, overgrazing is increasingly becoming a problem. In these areas, *Dasifora fruticosa* shrub and *Carex* grassland are mainly used for yak grazing and *Polygonum* and *Carex* grassland for Tibetan sheep. In this case, both systems have very similar husbandry income in total but the net income from the former system was higher due to less inputs and much income from other sections.

Keywords: Cold season, economy, grassland, sheep, yak

Introduction

Alpine shrubland, dominated by species, which have high resistance to arid and semi-arid conditions, covers an area of 116.4 thousand km² in China (MoA 1994; Yu 1998). *Dasifora fruticosa* shrub community is one of the yak's main grazing resources and habitats on the alpine meadow, and it has the highest grazing value compared with the other two types of alpine shrublands, *Rhododendron* and *Salix* communities. It is necessary to study the economic benefit for yak production utilising these cold season shrub types on the Qinghai-Tibetan Plateau.

Investigation methods

This study was carried out in 1999 in Zhuaxixiulong township of Tianzhu, Tibetan Autonomous County (TAC), Gansu Province, China. Two villages were selected as the research area.

Grazing resources

The topography in the research area is quite complex due to the topographic effect of Maya Snow Mountain to the south and Leigong Mountain to the north. Jinqiang River goes through the valley from west to east. Various land forms and plant communities are

distributed along the river and mountains. Our study sites, Daiqian village (3200 metres above sea level (masl)) and Nannigou village (3000 masl) are located in the Jinqiang river valley and belong to the Zhuaxixiulong Township. The two villages are neighbours, but possess two different types of cold-season grassland as grazing pastures. The grassland type was determined through routine vegetation investigation methods.

Animal production

Herders of the two villages use the shrubland as summer pasture for yak and Tibetan sheep. All animals are driven there for grazing from mid-June to mid-August. This shrubland is around 3600 masl and it is far away from herders' winter houses, so it has not been contracted to individuals and fenced. All animals in the village can have access to the pasture freely in the summer season.

In 1999, we visited 70% of herders in Daiqian and Nannigou and all of them completed the questionnaire we designed for this investigation.

Results and discussion

Grassland usage features in the two villages

Based on the comprehensive and sequential classification of grasslands, we surveyed and compared the pastures at Daiqian and Nannigou. The main vegetation types of alpine grassland are *Rhododendron* and *Dasifora fruticosa* shrubs, which are grazed by animals at Daiqian in summer and at Nannigou in summer and autumn. Meanwhile, the main vegetation type of subalpine grassland at Daiqian is *Dasifora fruticosa* shrub, which is distributed in the lower areas with an abundance of sunshine and usually used in cold seasons (winter and following spring). The accompanying component of *Dasifora fruticosa* shrub, *Salix* shrub, is distributed near the riverbed and used in autumn. On the contrary, the subclass of cold season grassland at Nannigou is alpine meadow, and its main vegetation types are *Carex* and *Polygonum* mixed with *Carex*. Under the natural selection, the alpine shrubland above 3200 masl is mainly grazed by yak, because yak have much stronger tolerance to cold. Meanwhile, the alpine meadow around 3000 masl is more suitable for sheep, because the tolerance ability of sheep to cold is weaker than yak although their productivity is higher than yak. There is no obvious evidence of degradation of summer and autumn grasslands in the two villages. As to the cold season grasslands, the degradation phenomenon is quite common, e.g. at Nannigou rodents seriously damage the vegetation.

By the end of August, herders return from the upper shrubland to the autumn pasture grasslands with their animals. The autumn pasture is much nearer to their houses, followed by movement to winter settlement areas, where they stay a relatively longer period of time. In this duration, they harvest their oat crop and make it into hay for winter supplementation. Animals are in good condition in fall and most adult animals are fattened quite well, so herders begin to sell a few for purchasing necessary commodities such as flour, vegetables and hay when needed.

Animal production in the two villages

Yak and Tibetan sheep are raised both at Daiqian and Nannigou, and the data concerning animal production are shown in Table 1.

Table 1. Characteristics of pastoral production at Daiqian and Nannigou.

Items	Daiqian	Nannigou
Area of grassland for cold seasons (ha/person)		
Natural	4.00	3.07
Artificial	0.13	0.13
Number of yak		
Total (per capita)	9.42	5.21
Adult male yak (%)	4.13	1.16
Adult female yak (%)	54.28	63.95
One-year-old yak (%)	27.43	21.51
Reproductive efficiency (%)	50.53	33.64
Number of sheep		
Total (per capita)	5.14	11.94
Adult male sheep (%)	1.00	1.78
Adult female sheep (%)	60.08	55.08
One-year-old lamb (%)	27.03	35.79
Reproductive efficiency (%)	44.50	64.98
Carrying capacity (sheep unit/ha)	8.09	8.62

Note: Normally, a yak equals to 3 sheep units on average (GAU 1985).

Oat hay fields in the two villages are similar, and their grass yield is around 12 t dry matter/ha. However, the area of natural grassland at Daiqian is 4 ha/capita, which is 130% of that at Nannigou. The edible grass yield of artificial grassland is 1.1 t/ha (Hu 1984; Yu 1998), which is higher than 0.9 t/ha of the average yield in China (MoA 1996). The reserve rate of grass yield of shrubland and grassland are 60% and 55%, respectively (Chen 1996). The number of yak and sheep is 9.42 and 5.14 heads/capita in Daiqian, and 5.21 and 11.94 heads/capita in Nannigou, respectively. This translates to 33.47 and 27.57 sheep units per capita at Daiqian and Nannigou, respectively. The current carrying capacity of grassland in the two villages would be 8.09 and 8.62 sheep units per ha within 150 days' cold-season grazing. It means that each sheep units of the two villages can only share 0.71 kg and 0.79 kg grass per day, respectively. According to the research results, the amount of diet supply for sheep should be at least 1.5 kg/head per day so that the body loss could be avoided during the cold season (AGEG 1979). The forage shortage for animals in the two villages, therefore, would be 52.7% and 47.3% of estimated feed requirements, respectively.

It is indicated that the reproductive efficiency of yak at Daiqian is 50.21% higher than that at Nannigou in spite of less adult females. This might be due to the lower carrying capacity at Daiqian. On the contrary, the reproductive efficiency of sheep at Daiqian is 31.51% lower than that at Nannigou in spite of more adult females. This is because the reproductive age is 1 month late at Daiqian than Nannigou and the proportion of local

sheep is quite high at Daiqian. It is suggested that the yak is more adaptable to the shrubland than sheep since the yak has stronger resistance to harsh conditions (Wu and Tu 1986).

Comparison of the economy of the two villages

The main annual income of herders comes from: a) selling wool, butter, and live animals; b) salary as casual labourer at the nearby gold mine; and, c) digging and selling medicinal herbs. The normal annual expenditure of herders includes: a) education fee for their children; b) cost of medicine for people and livestock; c) cost for daily life (flour, plant oil, vegetables, wine and tea etc.); and, d) cost for grassland reconstruction (fence, oat seeds etc.).

It is concluded from Table 2 that the main income of the two villages comes from yak and sheep selling. The income from yak and butter selling at Daiqian is 123.4 RMB Yuan (US\$ 1 = 8.2 RMB Yuan during this survey), which is 200.8 Yuan more than that at Nannigou. However, the income from sheep and wool selling at Nannigou is 114.1 Yuan, which is 119.8 Yuan more than that at Daiqian. This results in a similar income between the two villages.

Income from casual labour and medicinal herb collection at Daiqian is 267.7 Yuan per capita, nearly 3 times that at Nannigou. The total income at Daiqian is thus increased by 19.2% compared with Nannigou.

The cost for daily life, children's education and healthcare is similar in the two villages, but the proportion of yak at Daiqian is more than that at Nannigou and the cost of yak raising is much less than sheep. Meanwhile, the cost of input for pasture fence at Nannigou is more than that at Daiqian, so the total cost at Daiqian is much lower than Nannigou. The total net income of herders in Daiqian is twice that of Nannigou.

Table 2. *The economic situation at Daiqian and Nannigou (RMB Yuan¹ per capita).*

Items	Daiqian	Nannigou
Income from animal production	1,786.1 (82.12%)	1,725.8 (93.44%)
Wool	136.2 (6.26%)	256.0 (13.86%)
Butter	425.0 (19.54%)	224.2 (12.14%)
Live yak sale	841.7 (38.70%)	718.3 (38.89%)
Live sheep sale	383.2 (17.62%)	527.3 (28.55%)
Income from other sections	388.9 (17.88%)	98.9 (6.56%)
Medicinal herbs	125.1 (5.75%)	30.3 (1.64%)
Casual labour	263.8 (12.13%)	68.6 (4.92%)
Total income	2175.0	1824.7
Total expenditure	1272.4	1393.4
Net income	902.6	431.3

1. US\$ 1 = 8.2 RMB Yuan during this survey.

Closing remarks

The proper carrying capacity of alpine meadows is just 0.98 sheep units/ha per year (MoA 1996). But the actual stocking rates of the two villages, Daiqian and Nannigou, are 8.09 and 8.62 sheep units/ha per year, respectively, in the grazing period (from January to May), which is far beyond the standard. This would imply that the grassland in the research area is heavily overgrazed in winter and spring, a situation not readily observed during this research project.

According to the estimate of carrying capacity, the shortage of forage supply during the cold season at Daiqian and Nannigou would be 52.7% and 47.3%, respectively, therefore, the body weight loss of livestock cannot be avoided under the present situation.

The adaptability of yak to harsh conditions is much stronger than sheep, and alpine shrubland is more tolerant to grazing than *Carex* grassland, so the traditional yak production system possesses higher development potential than Tibetan sheep production system. Referring to those economic benefits, the two production systems show no much difference due to similar market system, the income of herders at Daiqian from yak raising is higher than Nannigou, and the income of herders at Nannigou from sheep raising is higher than Daiqian, so the total benefit from animal production in two systems is similar. However, the total income and net income at Daiqian is much higher than Nannigou since the partial income comes from non-animal production sectors.

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Yak hybridisation in the central upper slope region of Nepal: A community resource management strategy

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Summary

Sustainable socio-economic development of the upper slope regions of Nepal is reliant on the efficient management of community or common property resources (e.g. forest and non-timber forest products (NTFP), pasture, animals and human capital). The yak hybridisation production system is an integral component of the ecosystem in the upper slope areas of Nepal and a major economic activity, heavily reliant on pastureland and oak forest (*Quercus semicarpifolia*) resources. However, over the past 2 decades, these resources have been increasingly exploited and the available natural resources are now estimated to be beyond the limit of regeneration. As a result, the oak forests are showing signs of deterioration with poor regeneration, the alpine pastures are heavily infested with undesirable and unpalatable weeds and quality and quantity of feed production are deteriorating rapidly. Available medicinal and aromatic plants and other forest products have also seen a dramatic decline in many areas. Over the last 2 years, the Nepal-Australia Community Resource Management Project (NACRMP) has been working towards a management strategy for the upper slope resources of the Central Region of Nepal. NACRMP's approach involves the use of Participatory Action Research methodologies as a framework to empower communities and encourage collaborative decision-making. The major principles of the NACRMP strategy include: The use of indigenous knowledge and local organisations; a participatory approach involving all stakeholders; a system approach that considers environmental, socio-economic, and production demands; identification of appropriate interventions directed towards resolving livestock grazing related issues and an evolutionary approach to the management and protection of upper slope through existing forest policy and legislation. The major efforts of NACRMP are focused on: improved oak forest and pastureland management practices; formation of Forest User Groups (FUG) responsible for the management of the community forests (primarily oak forest) near their villages and development of grazing and NTFP user right systems for those communities forests.

Keywords: Common property resources, Nepal, oak forests, participatory action approach, pasture development, upper slopes

Background

During the last 30 years, the series of Nepal–Australia forestry projects have successfully implemented a sustainable community forestry system in the middle hills of the Central Region of Nepal. As a result, community forestry has been recognised as the major natural resource management strategy for the development of the forests in the middle hill regions of Nepal by His Majesty’s Government (HMG/Nepal) through the Ministry of Forest and Soil Conservation.

Through extensive studies conducted by the Nepal–Australia forestry projects, it became evident that the upper slope forests are an important natural resource base that has been neglected by the government and aid agencies probably due to relative inaccessibility (in terms of terrain, distances from roads and villages, and climate). The natural resources have been over-exploited and often mismanaged leading to overall deterioration of the available resources, particularly oak forest (*Quercus semicarpifolia*) areas and pasturelands (Jackson et al. 1993; Messerschmidt and Rayamajhi 1996; Jackson et al. 1998; Miller 1999).

NACRMP was designed to focus on community resources beyond just forests. The current project has recognised that the socio-economic development of the upper slope regions of Nepal is reliant on the management of community or common property resources e.g. forest, NTFPs, pasture, animals and people. Consequently, the project will attempt to develop and institutionalise a community resource management system for the management of resources in the upper slope areas of Sindhupalchowk District of Nepal.

NACRMP has adopted a participatory action research approach on the management of community resources through the involvement of stakeholders, especially the local women. The project selected the Tashitang–Bagam–Chhagam upper slope area of the Sindhupalchowk District to develop a community resource management demonstration model for the oak forest areas and pasture lands.

The upper slopes—A general description

Definition

The upper slope areas within the NACRMP are defined as areas between 2000 and 4000 metres above sea level (masl) in the mountain zone of the Maharabhat Lekh in Kabhre Palanchok District (Messerschmidt and Rayamajhi 1996). Temperate broadleaf tree species (e.g. rhododendron, oak, and birch), conifers (hemlock, fir), mixed forest, shrub lands and forest meadows dominate the forests in these areas. Above the timberline (about 4000 masl), the rangelands extend up to 5000 masl.

Much of the project’s upper slope areas are above 2000 masl in elevation. They are relatively inaccessible and much of the terrain is steep in nature. The forest areas are large and have good forest cover in those areas that are inaccessible. The climate is often extreme with long winters and heavy snow cover. The biodiversity is high and has remained unchanged in many remote areas. Human population is decreasing in most of the areas due

to out-migration. Because of the physical and climatic limitations, the upper slopes are only suitable for livestock grazing and marginal crop production.

Farming system

The farming system for the project site at Tatopani and Listikot village development committee (VDC) of Sindhu Palchok District is typical of many of the high elevation areas of Nepal. Forests and grazing lands in the upper slopes are generally found in elevations above the upper limit of cultivated agriculture, but their uses by local inhabitants are prevalent.

The agriculture production system is restricted to the high altitude valleys, which have good soil fertility and water availability. It has a low input base with heavy reliance on organic manure. The animals are mostly raised under a transhumance system. Livestock population in these areas is decreasing due to the deteriorating condition of the grazing lands and also due to lifestyle changes caused by mountain tourism. The development of these areas has received little attention. No formal implementation of the community forestry/FUG approach has yet been tested. Women play a key role in the management of the upper slopes, yet they have received little attention.

Yak and yak hybridisation production

The yak (*Bos grunniens*) and yak hybrid (*Bos grunniens* × *Bos indicus*) production system is an integral component of the ecosystem of the mountain and upper slope areas and is a major economic activity of those communities. Yaks live in mountain areas (above 3000 masl), while yak hybrids are predominantly raised in the upper slope regions (above 2000 masl). The yak and yak hybrids are managed by a traditional transhumance management system i.e. the herders move with their herds as they graze.

These animals have multi-purposes and are consequently priced higher compared to *B. taurus* and *B. indicus* breeds. They provide protein to the mountain communities in terms of milk, milk products and meat. The animals are well adapted to cold climates and are used for draft as well as transportation. Their tail switches are of great religious significance not only for Buddhists, but also for Hindus. Their body hair and hide is widely used for many household goods.

In the mountain areas of the Central Region of Nepal that cater to tourists, the male hybrid (*jhopa*) is increasingly used for transporting, trekking equipment and commercial products. These animals carry up to 60 kg loads and cover a distance of 20 km a day (Shrestha 1990). *Jhops* are more versatile than yak as they can survive comfortably below 2000 masl. The female hybrid (*chauri*) is raised to produce milk and milk products such as butter and cheese (*ghee* and *chhurpi*) for home consumption and increasingly for the domestic and international markets. *Chauris* can produce 300–540 litres of milk in 120–180 days or 2.5–3.0 litres of milk per day. *Chauri* milk is approximately 6.5% fat and 10.9% non-fat solid (Joshi 1982; Shrestha 1990).

The purebred female yak (locally called *nak*) are not good milk producers, but they are hardy animals able to withstand extreme cold and snow blizzards. The *naks* normally

produce approximately 220 litres of milk during an average lactation of 167 days or 1.3 litres of milk per day (Shrestha 1990). The milk is high in fat (above 6.6%) and non-fat solids are approximately 11%. These animals are also good source of organic manure for cropping and as fuel.

The yak and the *chauri* crossbred are anoestrus and the mating season occurs during July to October, when they are still in the alpine pasture areas. Parturition occurs during April to July in the lower elevations, closer to the home villages. First mating occurs at about 3 years of age and first calving at about four years of age. The calving percentage is about 55% (Shrestha 1990) and calf mortality is quite high (22%). Only *chauris* and first cross *jhopa* are kept and progeny of *chauris* are culled, as they are uneconomic to maintain.

Livestock grazing is widespread in the forests, mainly by yak hybrids and to a lesser degree cattle, sheep, and *bhaisi* (water buffalo). During the monsoon season (June–August/September) the yak hybrids graze the alpine pasture areas (2000–5000 masl) and gradually move down to the lower altitudes as the temperature decline. As the hybrid herds move up to the alpine pasture areas, other ruminants e.g. sheep, goats, buffaloes and cattle move up from the middle hills and are allowed to graze the pasture areas left behind by the *chauri*.

In the upper slope areas, where domestic and international markets are now accessible, the *chauri* population is increasing due to increasing demands for ghee from Lhasa and for *chhurpi* from Kathmandu. These animals rely on the available feed resources from pasture areas (*kharkas*) and oak forest areas. As a result, there is an increasing pressure on the *kharkas* in both the alpine as well as the upper slope forest areas. This increasing grazing pressure has forced livestock owners to use oak leaf fodder, especially during the winter months when there is feed shortage in grazing areas around the villages. Consequently, these natural forest resources are showing severe signs of over-logging.

The *kharkas* are also heavily infested with undesirable and unpalatable weeds due to overgrazing. The palatable species are selectively grazed and have the least chance of recovery or regeneration leading to gradual reduction in the feed supply and quality and ultimately reducing the carrying capacity of the majority of the *kharkas* in the area. Certain forest types, such as oak forests, are widely used to supply tree fodder to livestock in the winter and spring. Women play a key role in managing these upper slope forests, as they are the principle harvesters of the products.

Tenure and land use

Users from nearby villages through customary law traditionally manage many of the *kharkas*. The users are not charged for grazing or tree fodder collection. However, 'outside' herders, visiting or passing through the areas, are allowed to graze and are charged according to herd size. *Chauri* raising appears to be the major livelihood for the Tashitang, Bagam and Chhagam villages and there is little cultivation of crops. In fact, many *bari* lands around these villages have been abandoned and have reverted to native vegetation, mainly grasses and other plants of forage value to livestock. These abandoned terraces provide opportunities for development of improved pasture.

White clover (*Trifolium repens*) is already well established in many of the forest meadows from pasture development efforts initiated about a decade ago. However, in terms of livestock and forage production the system appears to be maximised. Consequently, it has been difficult to introduce rotational harvesting of fodder from oak trees without first providing additional forage supplies possibly from pasture establishment in abandoned fields around the villages.

Market influences

Market demand is having a marked effect on the lives of the people in the upper slopes in the NACRMP areas, despite its inaccessibility. The butter and traditional yak cheese (*chhurpi*) market, in neighbouring Tibet and in Kathmandu appears to drive the economy in the area. Farmers have gradually moved from being subsistence farmers to more specialised livestock producers and they have readily adopted dairy product processing technology (cream separators and cheese presses).

The availability of cash income has enabled many households to renovate existing or construct new houses, in spite of the fact that much of the time for many family members is spent with the herds in temporary shelters or *goths*. Most houses now have tin sheets for roofing, which reduces the need for wood shingles. On the other hand, markets for some products, such as *Taxus baccata*, a valuable NTFP, have led to its almost complete extirpation from the area. Tourism is increasing and could be of considerable potential in the future.

Role of women

Women play an integral role in the agropastoral system of the upper slopes. They make important decisions concerning the management and use of the natural resources and are responsible for many livestock production activities. Improving the management of the natural resource of the upper slopes, raising livestock productivity and improving living standards will therefore have to focus on women. These efforts will need to reduce women's time constraints, remove barriers to women's access to credit and improve women's educational levels so that they can more effectively participate in decision making and marketing.

Major issues

Researchers and community members of Bagam, Chaggam and Tashitan, through a number of participatory/rapid appraisal surveys and situational analyses, identified the following major issues associated with the upper slope forests areas and grazing lands:

- Lack of knowledge about forest and grazing land conservation and management techniques.
- Poor management and use of the natural resource base (e.g. overgrazing, excessive lopping of oak tree leaves for animal feed, uncontrolled fires, exploitation of NTFP etc.) resulting in the degradation of the resource base.

- Lack of alternative employment opportunities for villagers, which necessitates a strong reliance on forest, grazing land and animals as resource base for livelihood.
- Encroachment into the forests by villagers from outside the area. This is increasingly prevalent and due to the upper slope forests not being designated as community forests.
- Conflicts between communities over village boundaries and traditional land use and tenure.
- The large size of the forests complicates the development of a community forest operational plan, based on models from community forests in the middle hills.
- Limited access to livestock extension and animal health and other technical services has hindered the improvement in the herd/resource management system.
- Limited and inadequately trained department of forestry (DoF) staff that are assigned to work in the upper slopes on forest handover.
- Inadequate knowledge of selection and breeding of animals has eroded the herd productivity in general.
- The traditional access to replacement animals in Tibet has been increasingly difficult leading to genetic erosion, although the general trade has picked up lately.

Opportunities

Despite the issues outlined above, there are also a number of unique opportunities that can be capitalised on to promote improved management of the natural resources in the upper slopes. These include:

- fairly homogenous Sherpa communities
- traditional forest and grazing management systems that can be improved
- a keen desire among the local population for community forestry
- potential for developing improved pasture, which could help take the pressure off the forests to supply forage and fodder
- potential for increased NTFP harvesting
- a growing awareness among the government and forestry professionals of the unique demands of the upper slopes.

Management strategy

The strategy developed for the sustainable management of the upper slopes focuses on livestock and the provision of forage and tree fodder for livestock. The production of firewood, timber, and NTFP are important, but it is the use of the upper slopes for livestock production that demands urgent attention if the management of these areas is to be improved.

The strategy also attempts to improve agricultural cropping practices in the upper slopes, as crop production is an integral component of the farming system. The strategy also encompasses the social realm, so that the local population's livelihoods are improved and they are empowered to better manage the process of development.

Addressing livestock related issues, unfortunately, will not be an easy task because, at least in the short-term, the livelihoods of the people residing in the upper slopes are dependent on livestock. There are few other options available to these communities at this time. In addition, efforts to improve forage production and animal husbandry practices are interventions that require long-term time frames and for the upper slopes this is compounded because we have so few technical packages that can be readily applied.

In the upper slopes, where there has been only limited experience with community forestry, fresh perspectives and innovative approaches are required when developing a strategy for improving the management of these natural resources. Standard approaches to research and development need to be adjusted to the unique conditions of the upper slopes and all of the stakeholders need to be involved in the research process and in the planning and implementation of interventions.

Based on the issues and opportunities identified above by the communities of Bagam, Chhagam, Tashitang and Duguna, a strategy for the management of the upper slope resources was developed by the project to include the following principles:

- participation of all stakeholders in the major decision making process and the management of community resource and community development
- a clear vision of its future in the management of community resources and livelihood of the people concerned
- identification of appropriate interventions directed towards resolving livestock grazing related issues
- adoption of integrated systems approach to embrace all the environmental and socio-economic factors, which will influence the production system with the balanced use of the community resources
- adoption of participatory action research methodology as the framework for research, planning and implementation to empower communities and to encourage collaborative decision-making among communities and the government
- utilisation of indigenous knowledge and building on local institutions
- an evolutionary approach to the management and protection of upper slopes through existing forest policy and legislation by involving communities based on traditional approaches found successful elsewhere.

Priority interventions

After intensive consultation with community members and staff from the Department of Forest (DoF), the following prioritised interventions were identified.

Formation of FUG and forest handover

Forest User Groups (FUG) have been established at Tashitang–Duguna villages of Tatopani VDC for the Ponthali forest and another FUG at Bagam and Chhagam of Listikot VDC for the forest above these villages. The size of forest to be handed over has

presented special problems generally not found in the community forest process in the lower elevations. The potential community forests are not small, discrete forest areas, but rather, stretch from just above the village up to the timberline and encompass thousands of hectares. Grazing also takes place in *kharkas* within the forest and herders construct temporary shelters (*goths*), to live in while taking care of their livestock (namely the yak-cattle hybrids). Such conditions are not found in lower elevations, where the bulk of community forestry activities have been implemented.

The oak forests of the upper slope are types demanding the most immediate management, but the villagers view the entire forest area as their forest. It is therefore essential that the management responsibility for the entire upper slope forests and grazing lands be devolved to the communities so that they can begin protecting, managing, and better utilising the resources.

DoF staffs have been extremely reluctant to handover the entire forest to the community since a standard operational plan for a community forest requires detailed data on the forest stand and boundaries must be clearly marked. The project is currently in the process of trying to convince DoF staff to handover the entire forest to community management with a detailed operational plan prepared for the oak forest type and a more simplified plan for the remaining forest area.

What is essential in this process is that the handover process is initiated and that a plan be prepared to begin improved management. The upper slope ecosystem requires flexibility and innovation in the community forestry process. Even if the forest is not officially 'handed over' to the community, the community should be empowered to start protecting the forest and to improve the management of the resources found there.

A monastery and nunnery at Chhagam also provides an excellent opportunity to establish a fuel wood plantation using fast growing species such as Nepalese alder (*Alnus nepalensis*, or *Utis* in Nepali) and willow (*Salix spp.*). If the monastery/nunnery could obtain a larger portion of their firewood requirements from a fuel wood plantation this would help to reduce pressure on the forests at least in that immediate area.

Formation of grazing user groups (GUG)

To better manage livestock grazing in the upper slopes, GUG are being formed and a system of grazing permits established. The objective of forming GUG is to minimise the impact of livestock grazing on the natural resources and to initiate improved management of the grazing lands. Grazing area user rights are being respected and existing traditional systems are built upon as much as possible. Grazing Area Operational Plans (GAOP) will be prepared, which will include grazing permits valid for a period of 5 or 10 years, which will indicate the number of livestock allowed, the *kharkas* to be used, and the periods in which to use the different *kharkas*. Such permits will enable the GUG Committee to plan, monitor and evaluate the use of the grazing lands. The GUG will also be encouraged to initiate pasture development interventions to improve forage production in the *kharkas* in the forest and in the *bari* lands around and below the villages.

Mobilisation of women groups

Participants of the project's women's literacy classes are organised into small women groups within the framework of the community forest user group. It is hoped that this strategy will improve their resource management and resource generation skills and allow access to a range of services and opportunities provided by the different line agencies and non-governmental organisations (NGO).

Assessment of grazing lands

A rangeland assessment programme has been initiated to determine if the long-term productivity and biodiversity of the rangelands is being maintained under the present grazing systems. All stakeholders will need to have a clear idea of what they want to be managing the rangelands for. Simply stated, management goals for the upper slope rangelands may be to ensure that nutrient budgets, vegetation productivity, and overall ecosystem health are at least maintained and, ideally, improved. The *chauri* herders in the upper slopes of Sindhu Palchok will probably be the ones who can identify true indicators of vegetation change. Realistic rangeland monitoring programmes will therefore need to incorporate this indigenous knowledge.

Grazing land assessments in the Bhairav Kund Lekh area will try to at least provide:

- a better understanding of vegetation species composition in the different plant communities and the dominant plant species
- identification of 'increaser' and 'decreaser' plant species (i.e. those that are increased with grazing and those that decline with heavy grazing)
- an estimate of forage productivity
- livestock use of the grazing lands (livestock numbers, herd movements, stocking densities etc.).

Pasture development

Pasture development will be a key intervention in the upper slopes. In the past, pasture development using white clover and other temperate grasses (e.g. cocksfoot *Dactylis glomerata* and Italian ryegrass *Lolium perenne*) was carried out in the *kharkas* in the forest and today one sees the benefits of these successful efforts with clover widespread in the forest meadows. It is now recommended that efforts in pasture development be targeted towards areas in proximity to the villages and on abandoned *bari* lands around and below the villages.

These areas provide a fertile ground for establishing improved forages that could be used on a cut-and-carry basis that could be grazed by livestock, or as lands for making hay to provide supplemental feed during the winter (thereby reducing pressure on the oak forests to supply tree fodder). A combination of grazing and cut-and-carry or haymaking could also be practised (i.e. grazing early during the rainy season and then cutting for hay in mid-October). It is therefore recommended that initial efforts be directed towards developing improved pastures for haymaking. Emphasis will be given to introduce a mix of

taller growing, leafy, hay type varieties of improved temperate forages such as cocksfoot, tall fescue (*Festuca pratense*), and Italian ryegrass in association with clovers or other legumes such as *Maku lotus*.

Policy implications

An appropriate policy framework is also essential to ensure that a participatory resource management strategy can be actively pursued in the upper slope forests and grazing lands in Nepal. There are a number of special policy-level concerns that require attention.

Research

The ecology of the upper slope forests and grazing lands are still poorly understood, which hampers more effective management. Information on socio-economic aspects of communities in the upper slopes is also lacking, which constrains work to assist communities to organise forest and grazing user groups. Concerted effort will be made to address these knowledge gaps through both applied and adaptive research.

Monitoring

Monitoring of the condition of upper slope forests and grazing is critical to understanding how management practices are affecting the quality of the natural resources. A combination of aerial photographs, baseline assessments, and practical ground-trusting methods will complement more qualitative measurements. Establishment of photo points for repeat photography over time will provide an easy starting point and enable local people, who are using the resources, to better understand the changes taking place in the upper slopes.

Re-orientation and training of DoF staff

To work effectively in the upper slope forests and grazing lands, DoF staff will require re-orientation and training to the special concerns that these resources present. Developing specific lectures/courses on upper slope forests and grazing lands into the ISc and BSc Forestry syllabi at the Institute of Forestry will assist in making the new generation of foresters more knowledgeable about these resources.

Indigenous knowledge and traditional management systems

Making better use of the vast indigenous knowledge local people possess of the upper slope forests and grazing lands is necessary when making improved management plans for these resources. As it becomes more available, scientific information will build upon and complement the indigenous knowledge systems, not replace it. Similarly, certain aspects of

traditional management systems may offer considerable scope for improved management of the natural resources as responsibility for management of forests devolves to the communities. Central policy-level directives will be encouraged to give credence to indigenous knowledge and traditional management systems and ensure that they are given greater appreciation and consideration by DoF staff in the field.

Clarifying and disseminating the best options

Clarifying the best management options for the upper slope forests and grazing lands and disseminating this information to a wider audience in Nepal is important, since so little work has so far been done in these high elevation environments.

Income generation and access to capital for local people

To ensure sustainable livelihoods and reduce poverty for people living in the upper slopes, it will be necessary to move away from the widespread belief that community forests should only be used to provide for subsistence needs. Rather, the upper slope forests and grazing lands should be viewed as natural resources that, when managed sustainably, can generate income and provide options to secure greater access to capital. In the case of the upper slopes in the NACRMP, considerable additional income could come from NTFP.

Non-timber forest products (NTFP)

Existing government policies and legislation prohibit the collection and sale in unprocessed form of a number of high-value NTFP that are found in the upper slopes. This includes species such as Panchaule (*Dactylorhiza hatagirea*) and Yarcha gumbo (*Cordyceps sinensis*), which cannot even be collected and a number of others such as Jatamansi (*Nardostachys grandiflora*), Talispatra (*Taxus baccata wallichiana*), and Sugandhawal (*Valeriana jatamansi*) which cannot be sold in an unprocessed form (Amatya et al. 1995).

Many of these plants occur in the project areas. There is a growing perception that some of the NTFP banned from collection (e.g. Panchule and Yarcha gumbo) are not under any threat while plants which are allowed to be collected and sold in unprocessed form are being greatly exploited (e.g. Chiraito or *Swertia chirayita*, and Bhyakur or *Dioscorea deltoidea*). Current policies and legislation regarding NTFP will be reviewed and, if necessary, revised to more accurately reflect the opportunities for expanding collection of certain species and perhaps placing more control on the unsustainable exploitation of others.

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Current rangeland management in Zhongdian County, Diqing Tibetan Autonomous Prefecture, Yunnan, P.R. China

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Summary

Diqing Tibetan Autonomous Prefecture is located in the upper reaches of the Yangtze River in Yunnan Province. Due to the implementation of the logging ban in the upper reaches of the Yangtze River, the industry structure of Diqing has changed from timber to tourism, animal husbandry, biological resources and hydroelectricity. Animal husbandry has a long history locally; therefore the logging ban provides a good opportunity for animal husbandry development. Animal husbandry is the major industry in Diqing Tibetan Autonomous Prefecture. At present there are problems in developing animal husbandry. One of the most serious problems is the degradation of rangelands due to overgrazing, at the same time, Diqing prefecture is located in the southern part of the Tibetan Plateau and its altitude averages 3380 metres above sea level (masl). Thus the natural climatic condition is very severe and the lack of fodder in winter is problematic. In order to solve these two issues Zhongdian Animal Bureau has introduced Australian grass species to local people in 1990. Therefore the style of ancient nomadic grazing and farmland utilisation has been changed. Tibetan people of Zhongdian have accumulated knowledge regarding utilisation and management of artificial grasslands, the farmers are aware that the introduced Australian species are not suitable for the local physical conditions. Based on a one-year of intensive field surveys on the management of artificial grasslands, the present utilisation situation and associated issues regarding utilisation are discussed. Some useful suggestions on local animal husbandry are presented.

Keywords: Artificial rangeland, timber ban, management, Tibetan

Introduction

Physical geography

Diqing Tibetan Autonomous Prefecture is located in the North-West of Yunnan Province, on the south-eastern edge of Qinghai-Tibetan Plateau and the centre of Heng Duan

Mountain Range. It is located in between 98°37'–100°23'E and 26°57'–29°12'N. The total area is 23,870 km². It includes Zhongdian, Diqing and Weixi Lizu Minority Autonomous Counties. Diqing lies in the upper reaches of the Yangtze and Mekong Rivers.

The elevation ranges from 1530–5545 masl, the average altitude is 3380 masl. About 93.5% of the land is mountainous. The annual mean temperature is 5.5°C. Average rainfall is 700 mm per annum.

Vegetation

Diqing is located in a transitional zone in terms of geological, physiognomy and climatic movement. The area has high mountains and deep valleys. The Lancang (Mekong River) and the Jinsha (Upper reaches of the Yangtze River) run southwards side-by-side with the Hengduan Mountains. These form the world famous gorge area of these rivers and the Hengduan Mountain Range. The influences of both low and high altitudes in the Hengduan Mountain Ranges produce varied and colourful highland plants. It is the richest area of plants in China with more than 5000 highland species. The vegetation types can be divided into dry and semidry valley, open bush lands, evergreen broad-leaved forests and evergreen conifer forests of the subtropics, temperate and frigid conifer forests, alpine bush woods and the meadows, alpine scree and periglacial vegetation.

Population

The total population of the area is approximately 334,000 (Government statistic 1999), 84.8% of which are minority nationalities including 33.8% Tibetan and 29% Lizu.

Research methods and the research site

Research methods

Key informant interview: In this study, we interviewed key people from related government departments, such as the Grassland Station of Zhongdian Animal Husbandry Bureau and Zhongdian Forestry Bureau. We also interviewed the village leader and some farmers in Tuo Munan village.

Participatory Rural Appraisal (PRA) methods: Many PRA tools were used to collect information from farmers. The PRA tools include the following:

- Time Line: Documented the history of the village. Most importantly information about animal grazing was collected.
- Community Distribution Map: Includes the location of the village, natural grassland, artificial grasslands and summer pastoral lands. From this map we gain the area used by farmers.

- Natural Resource Trend Line: We found out the condition of natural resources and changes over 5 years.

Intensive field surveys: The characteristics of artificial grasslands (condition and plant species) in Tuo Munan village were surveyed.

Background of Tuo Munan village

Tuo Munan village belongs to He Pin Administration Village of Xiao Zhongdian countryside and is located in the south of Zhongdian County. The annual mean temperature is about 5.8°C. The annual mean rainfall is 849.8 mm.

Yak, cattle, yak-cattle crossbreeds, goats, horses, pigs, sheep and mules are raised. The farmers cultivate their fields once a year only and plant in early spring (from March to April in the lunar calendar) and harvest in late autumn (October). Barley (bare and husked varieties), buckwheat (bitter and sweet varieties), potato and *Brassica rapa* L. and other vegetables comprise the bulk of the year's yield.

Tuo Munan village has 500 mu (1 hectare = 15 mu) of natural grassland in 'La Bu', and it shares the natural grassland with another village. The farmers in Tuo Munan village began to plant artificial grasslands in 1992 and currently have 123 mu artificial grasslands.

Results and discussion

The present management of traditional grasslands

Tibetan herders in Zhongdian classify the rangeland into two types—natural rangeland and cradle rangeland. Natural rangeland includes summer pastoral (Tibetan word is Ri Gong), all year public grazing grassland and winter grassland (Tibetan name is Ge Gong). Cradle rangeland includes natural cradle rangeland and backyard for drying the fodder and barley.

There are three traditional nomadic styles in Zhongdian: ecesis, semi-nomadism and semi-ece-sis.

There is approximately 5.03 million mu of rangeland in Zhongdian that makes the development of grazing in Zhongdian viable. However, there are many physical and social factors to inhibit the development of animal grazing. For example, the plants' growing period is at most six months due to the cold and arid nature of the environment. All the plants die in October and grow again in May. Lack of fodder is serious in winter and spring. The cycle of animal grazing consistency with fodder availability, according to local people, is that livestock are born in summer, fattening in autumn, reducing over winter and dying in the spring.

The alpine rangeland becomes degraded with shrubs and weeds after several years. Traditionally, the herders congregate to dig a buffer zone and then burn the shrubs and weeds within the fenced area. On one side, the shrubs (including *Rhodendron* spp, *Quercus* spp) and weeds (*Stellera* spp.) are burned. On the other side, the ash is used to fertilise the soil. But Diqing government forbade burning grazing land, and open swidden land in one closed mountain pass area, so that this method of renewing grasslands cannot be carried

out. As a result, the area of pasture is becoming more degraded and a big conflict exists between grazing and forest in Diqing.

At present, because of overgrazing and invasion of weeds, the degradation of rangelands is very serious (Tu and Luo 1992; Wang et al 1996; Ma and Zu 1997; Wang 1997; Zhang et al 1998; Wang and Li 1999). Fragments of rangelands and the spreading of *Stellera* spp. are widespread in Zhongdian.

The condition of artificial rangelands

The Zhongdian Animal Husbandry Bureau has built thousands of mu of artificial rangelands in Xiao Zhongdian countryside since 1990. They chose four species of plants indigenous to Australia that were thought to be suitable to grow in Zhongdian. The four species are *Trifolium repens* L., *Poa annua* L., *Trifolium pratense* L. and *Lolium perenne* L.

The average fresh production of artificial grasses is 993.56 kg/mu and the maximum production is 1140.75 kg/mu. It is 2.32 times than that of natural grassland. If the grasses on artificial rangelands are harvested two times per year, one year's fresh grass production is equal to six years fresh grass production on natural rangelands.

The experience of managing and utilising artificial grassland by Tibetans

Local people's participation is vital to successful rangeland systems (Panjab Singh 1996). The farmers of Tuo Munan participate daily in managing and utilising artificial grasslands. Hence they have accumulated mature knowledge. The experiences of planting, land tenure, fertilisation, harvesting, grazing and benefits of artificial rangelands are discussed.

- **Planting:** Artificial grasslands were developed in May 1992 and have been planted three times. The first time the soil was ploughed by tractor and hand seeded, however, the seed was planted too deep and the grass did not grow well. In the third year (1995) they replanted again using drill seeding method, and the grass grew much better. The local people gained a great harvest from the artificial grassland. Three years later (1998) all the farmers of this village replanted again.
- **Tenure:** In many pastoral areas in China, land tenure intensifies the contradiction between privately owned livestock and communal land (Wu 1996). The farmers want to avoid overgrazing on the artificial grassland, so they ranked the quality of grass into two grades (good and poor), depending on the productivity and quality of the grass. Artificial grassland is divided among households according to the number of people. The area is divided so that each household gets an equal amount of good and poor grasslands. Their individual fields are then allocated by lottery. If two households with equal number of persons have different livestock holdings, the household with less livestock can exchange their excess hay for livestock products such as butter. People respect the boundaries between fields and rarely try to encroach on others grasslands. If there are any conflicts between two households regarding boundaries, the leader will check the division records, then measure the land again to make sure the boundaries are correct.

- Fertilisation: Sheep manure is mainly used as pig manure is too rich (too much N) and cow manure is too heavy and too big. If pig manure is used, the leaves of grasses turn yellow.
- Harvesting: Farmers plant artificial grasslands together but harvest their plots individually. In the grasslands men cut and women gather the grass. It takes seven days to harvest and place the grass on racks. In the first two years, the farmers harvested in the seventh month of the lunar calendar and in the third year they harvested in the ninth month of the lunar calendar. This year the seeds matured and fell into the land, so they avoided sheep grazing in the grassland and thus avoided replanting the following year.
- Grazing: As the animal grazes it also tramples the grassland and this impact is very important for plant community succession (Jiang 1988). At first they did not know much about the artificial grass and did not know if it was better or worse than native grass. On the one hand, they grazed the animals in the field all winter after harvesting but the next year the grass did not come up well in the next growing season. On the other hand, the fence was not strong enough to keep animals out of the area so the animals often went in and ate the hay after harvesting. Later they made a stronger fence and dug a trench around the field so that animal couldn't get into the area. Twenty days after harvesting they allowed the sheep to graze on the artificial grasslands but only for ten days. During this time they only allowed them in the area for a few hours a day in order to prevent bloat from the residual legume plant material. They kept the sheep from eating the new grass and also kept sheep manure from fertilising the land. They said sheep were most suitable for artificial grasslands as they are light, while cattle are too heavy, and pigs dig up the land. It does not matter if some households have more sheep than others as the sheep benefit all the fields and the remaining plant residue benefits the sheep.

Ten days after they harvest all the crops, the animals come down from the alpine pastoral area and graze freely in the public rangelands. All animals are kept out of the artificial grassland.

- Benefit: The farmers believe the grass yield of artificial grasslands is better than that of natural grasslands. They said one cow must eat 150 kg/day of fresh natural forage. Cattle have difficulty to resist cold in winter if they did not eat 130–140 kg/day fresh grasses in summer. However, with the artificial grasslands one cow only needs to eat 100 kg/day fresh artificial forage to live through the long and cold winter in Zhongdian.

From the practical experiences of the management and utilisation of the farmers, we can draw the following conclusions:

- a. The farmers replant the grasslands every 3 years and they avoid destroying the grasslands from overgrazing and trampling. They chose sheep to graze on the artificial grasslands for 10 days; this indicates they have paid attention to the sustainable production of artificial grasslands.
- b. They chose the animal species to graze on the artificial grassland and also chose the best manure to fertilise the pastoral lands. The managing experience is the result of selection and comparison over time.
- c. The farmers want to avoid the conflict of overgrazing on public grasslands so they employ a distribution system where individual owners manage together for individual

gain. The system indicates that clear land tenure is an effective management tool and can improve the activity and interest in participating.

d. They accumulate useful experience from the mistakes made at each stage.

Some difficulties in managing artificial grasslands

Tuo Munan village resolved the lack of fodder in winter times from 1992 onwards, so the animal's numbers are rising rapidly. However, the farmers believe it is difficult to manage artificial grassland and more and more farmers pay attention to the following difficulties:

- Higher labour investment: They need to fence the land, dig a trench and allocate people to care for the livestock. They must harvest grass once per year, and they also spend much time to dry and store fodder. The artificial grassland needs to be replanted every 3 years. All of these jobs require high labour investment.
- Artificial rangeland degradation: The artificial rangelands degrade in 2–3 years, but it is difficult to renew and needs replanting every 3 years.
- Artificial rangelands cannot graze many animals so now the farmers do not allow grazing, and they hand-cut and store fodder for future use.
- The spread of exotic species: The seeds of exotic species are spread through animal's faeces in surrounding forest and alpine pastures. As the cattle plough in the fields they excrete waste and the exotic grasses grow well and impact on the natural plant communities. Although intensive research on the impact of original species, and original ecological environment with exotic species has not been undertaken this problem cannot be ignored.

Recommendations

The relationship between protecting forestlands and returning farming land to grasslands

After the logging ban was implemented in 1998, Diqing prefecture invested 300 million RMB Yuan (US\$ 1 = 8.2 Yuan during this survey) to build rangelands around the Yangtze River. In addition, Diqing Prefecture has 15,704 thousand mu of wild lands in which to plant grass. The project of returning farming land to grasslands will be carried out step by step in 2000. The area of rangelands will be extended and the production of fodder will rise. This will provide a good basis for animal husbandry.

Repair of traditional pasture

The traditional methods for repair and renewal of pasture have a long history in the local area, and practical experience has proved these methods are feasible. Due to the difficulties in developing animal husbandry in Diqing Prefecture, the traditional methods are

important for repairing and renewing pasture in the local area. The co-operation of different government departments is an important way towards sustainable utilisation of the rangeland resource.

Local species grassland experiment

If we only notice the production of artificial grasses, we could conclude that the artificial grassland relieves local fodder shortages. But from our intensive interviews we see the artificial grassland need more labour input to maintain the normal production, and the ability to be renewed is limited. At the same time, its ability to be grazed is very poor. For these reasons, we may conclude the artificial grasslands of exotic species are not suitable to the local environment and climate.

The authors recommend the planting of artificial grassland with locally adapted species to gradually replace the exotic species in artificial rangelands in Zhongdian. The locally adapted species should be expanded gradually, collecting seed and replanting artificial grasslands.

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Sustainable development of rangeland resources on the Qinghai–Tibetan Plateau, P.R. China

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Summary

From a rangeland industry system point of view, the current situation and obstacles of pastoral resource management and development are discussed. Strategies for sustainable development of rangeland resources are recommended.

Keywords: Qinghai–Tibetan Plateau, rangeland, sustainable development, Tibetan sheep, yak

Introduction

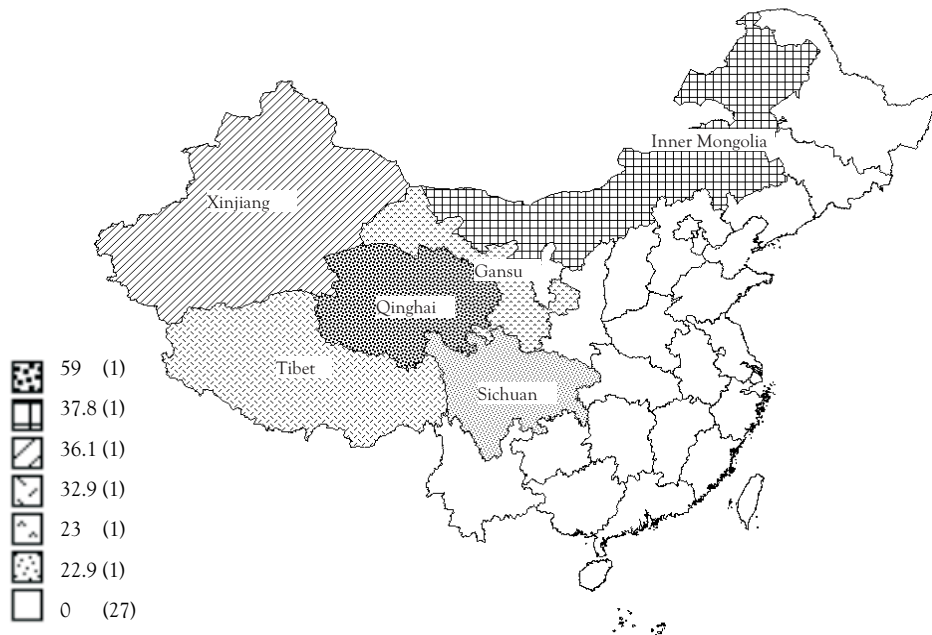
Between 1987 and 1997, the livestock production of Qinghai Province has dramatically increased through the initiation of the Reform Policy. Livestock numbers increased by 118.4% and meat production increased from 113.8 thousand tonnes to 198.4 thousand tonnes (Liu 1995). However, the ecological condition of Qinghai's rangeland environment has degraded due to various reasons, which are obstacles to sustainable livestock development. Accordingly, it is necessary to evaluate each of the contributing factors using the concept of rangeland industry system (Ren 1995), and make policy changes for improving and sustaining the grazing environment.

Rangeland resources in Qinghai Province

The main rangeland resources of Qinghai Province are located in the vicinity of Qinghai Lake, and are of the southern alpine meadow vegetation type. Elevations range between 1700–4000 metres above sea level (masl) (Zheng and Yu 1995). These rangelands comprise a total area of approximately 36.5 million hectare, which accounts for about 9.1% of China's rangeland area and represents China's fourth most extensive rangeland area (Figure 1). About 31.6 million hectare or 86.7% of this rangeland is usable. It is comprised of 16 rangeland types, 28 range groups and 173 subtypes (Figure 2). Among the 16 rangeland

types, alpine meadow at the height of 2800–4200 masl is the most extensive formation (29.6 million hectare), of which about 26.4 million hectare (83.7%) is usable by livestock.

About 2000 plant species have been recorded from the southern alpine meadow (Zheng and Yu 1995), around 800 of which are grasses and sedges forming the forage base of the livestock industry. This forage base has relatively low productivity but high nutrient content; i.e. high crude protein, crude fat, total non-structural carbohydrates, high caloric content, and low content of fibre (Sun 1994).

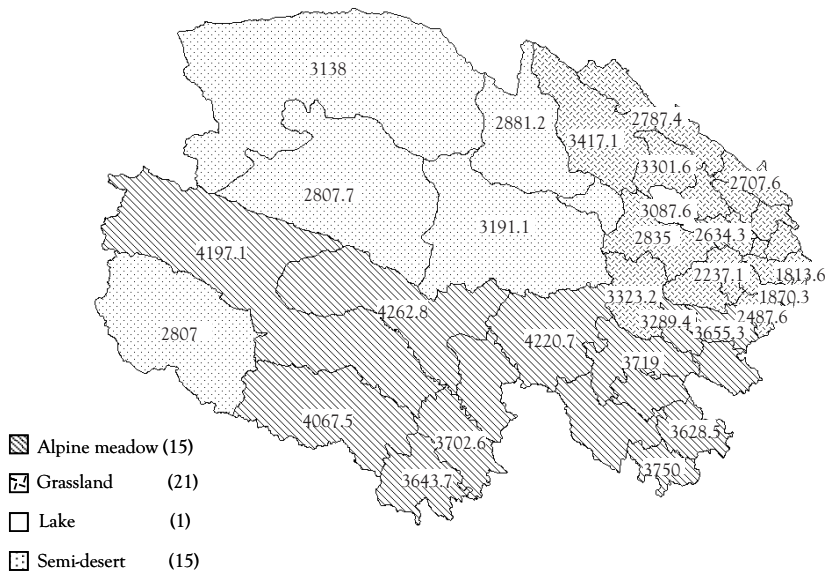


Data from Li (1992).

Figure 1. China rangeland distribution.

The vegetation is very tolerant to grazing. The growing season at these elevations ranges between 80–150 days/year, which helps to account for the very low plant height (other environmental conditions affect this too, like high evaporation, transpiration and wind) and low forage production. Dry matter yields average 893 kg/hectare in alpine meadows and 441 kg/hectare in dry alpine grasslands. Seasonal differences in forage biomass and nutrient vary between September when they are highest and May and June when they are lowest. Crude protein content reaches 11.2% in spring and summer and drops to 6.2% in winter (Sun 1994).

According to national criteria on rangeland classification (EC 1983), most rangeland in Qinghai belongs to grade 2, which covers an area of 20.3 million hectare and comprises 55.8% of the total range area in Qinghai. The rest of the range generally falls to middle or low grade. At present, there are 22.3 million livestock. Economic returns from Qinghai rangeland average about 3630 RMB Yuan/hectare (US\$1 = 8.2 RMB Yuan during this survey).



Data from EC (1983).

Figure 2. Qinghai rangeland types and distribution.

Obstacles for sustainable rangeland development

Rangeland deterioration and low productivity of livestock

Over 7.3 million hectare, or 19.9%, of Qinghai's rangeland resources have deteriorated and poisonous weeds dominate on about 1.3 million hectare. Furthermore, desertification is affecting 2.7 million hectare of Qinghai's rangeland resources (Zhou 1995). A survey in Hainan Prefecture showed that forage production of grasses, sedges and legumes dropped by 70%, while poisonous weeds increased 35.6 times between 1981 and 1996 (IFAD 1997). On *Potentilla fruticosa* L.-dominated rangeland, for example, grasses and sedges have decreased by 82.4% and 67.4%, respectively. Poisonous weeds surveys in the middle province have shown that fresh yield of *Stellaria chamaejasme* L., a poisonous plant species, averaged 1017 kg/ha in 1963; 2250 kg/ha in 1974; 4900 kg/ha in 1982; and 5437 kg/ha in 1996. Biomass yield on rangeland dominated by *Achnatherum*, *Stipa* and *Orinus* was 1740 kg/ha in 1963 but 1089 kg/ha in 1996. Again according to the IFAD (1997) survey, in Hainan Prefecture, loss of dry forage due to degraded rangeland reached 234.6 million kg in 1996, accounting for 9.77% of its potential forage output.

Consequently, livestock quality and productivity have declined on the degraded rangeland feed base. Investigations indicated that in the 1960s, the average carcass weight of yak was 250 kg, as opposed to 125 kg in the 1970s. The carcass weight of Tibetan sheep averaged 30 kg in the 1960s, as opposed to 20 kg in the 1970s. In the 1980s, the carcass

weight of yak averaged 51 kg at 1.5 years, 80 kg at 2.5 years and 110 kg at 3.5 years of age. The carcass weight of Tibetan sheep averaged 16.1 kg at 2 years, 18.6 kg at 3 years and 20.1 kg at 4 years of age (Qinghai Academy of Animal Science and Veterinary Medicine 1975, 1987, 1995). Because rangeland degradation and desertification caused reduction of livestock output, the province loses about 12 million tonnes of edible forage every year (8.2 million sheep units), which amounts to 1 billion RMB Yuan financial deficit (US\$ 1 = 8.2 RMB Yuan during this survey).

Loss of biodiversity

The alpine rangeland is a unique germplasm pool of alpine biodiversity. Over 5000 species of fungi, 12 thousand species of seed plants, 1300 species of vertebrates, including Tibetan sheep and yak, and 4100 species of insects exist in rangelands of the Qinghai-Tibetan Plateau (Yang 1997). This biodiversity is potentially a rich genetic resource of wild species and selection of domesticated varieties, both plant and animal. Unfortunately, poor management has caused the loss of some species and a loss of nutritious forages in the alpine environment and has reduced its biodiversity. A large area of *Achnatherum*-dominated pasture has been replaced by poisonous *Aconitum* species (IFAD 1997). *Oxytropis* and *Gentiana* weeds now occupy 50–70% of previously sedge-dominated summer and fall rangeland. It is necessary to take urgent measures to plan for the sustainable development of these rangeland resources to preserve their resources for future generations.

Snow disasters

At least 14 snow disasters have taken place since the late 1940s: 8 between 1950 and 1970, 3 in the 1980s and 3 in the 1990s (Zhou 1995). Snow disasters appear to be happening more frequently and are more serious than those of earlier decades. More severe winter weather is also threatening the fragile rangeland environment. In recent years, snowstorms, hail, drought, flood and frost in rangeland around Qinghai Lake occurred more frequently. Recently, serious soil erosion from the deteriorated ranges at the headwaters of two of China's great rivers, the Yellow and Yangtze, caused floods in lower reaches of the rivers which incurred great human life and financial losses.

Vulnerable ecology and global climate change

The Qinghai-Tibetan Plateau, with its harsh natural climate, is very fragile ecologically, which makes it hard to recover when it is damaged. Some scientists believe that desertification caused by global warming is the main reason for the deterioration of rangelands located in semi-drought/semi-humid belts, such as Dari County in Qinghai Province. A ground survey and National Oceanic and Atmospheric Administration (NOAA) images taken in 1985 have shown that the index of desertification in Dari County such as temperature increase, deterioration of vegetation and soil, and degradation

of water quality, changed significantly from 1985 to 1997 (Ma 2000). In the territory of Dari, alpine meadow occurs mostly in the dry and upland area of north-west of the plateau. Bush vegetation, however, occurs in the lower and warmer areas of the south-east. The distribution of deteriorated rangeland also appears to follow the same pattern. This suggests that desertification in Asian inlands impacts significantly on rangelands in parts of Qinghai like Dari.

Human activities and rodent damage

Some scientists believe that human activities like over-stocking and rodent damage contribute most to degradation. Over-utilisation by livestock and rodents causes damage to sod and loose soil, which, consequently, can be easily motivated by wind, water, freezing and thawing, then water and soil erosion starts in the areas with poor sod and soil texture

Recommendations for the sustainable development of rangeland resources

Construction of a legitimate system for rangeland management

Government laws, regulations, and rules for effective management and protection of rangeland resources should be put into effect. A rangeland management system that balances the forage resource with the proper stocking rate needs to be established. Rangeland productivity and livestock economic production can be profitably combined. Stocking rate control is a fundamental measure of sustainable development and environmental protection of the rangeland resource (Zhou 1995). Depending upon the health condition of any specific rangeland site, the provincial and local Rangeland Monitoring Organization is responsible for destocking on degraded or desert rangeland. Rotational grazing, exclusion of livestock on severely degraded ranges, and rangeland re-vegetation can be deployed to rehabilitate degraded rangeland. This will ensure that the livestock industry and development of rangeland resources are acting in concert.

Integrated techniques

To halt the current trend in deterioration, an integrated technical package, matched with proper stocking rate and utilisation, should be implemented to rehabilitate degraded and deteriorating rangeland. In Inner Mongolia, for example, an integrated package has increased plant cover of degraded rangeland by 3.6 times, forage output has increased by 5 to 8 times, and carrying capacity by 3 times on 370 thousand hectare of desert rangeland (Li 1994). In northern Inner Mongolia, technical packages were implemented to improve 1.5 million hectare of rangeland, on which plant cover increased greatly. Livestock fibre production increased three-fold, cashmere production doubled, and livestock production

increased by 67% (Li 1994). Integrated techniques of fertiliser, reseeding, weed and rodent control have been considered effective for rangeland improvement. In Qinghai, plant growth and reproduction is limited by the availability of soil nitrogen and phosphorous even while the accumulation of soil organic material is high because of low annual temperatures and local soil types. It is estimated that range forage production could be increased a dozen times by means of fertilisers. The authors of this paper strongly emphasise the application of fertilisers, which improve the soil condition and the ecological system together.

Fodder as an alternative forage resource

Animal scientists and agricultural economists in China and abroad, however, acknowledge that rangeland livestock production is not usually sufficient in itself to provide an adequate feed base for a dynamic and profitable livestock industry (Li 1994). Forage crops are a huge alternative resource for high output, high quality, and sustainable production of the modern livestock industry. Forage production is very necessary to supplement livestock feed during periods of seasonal deficiency. *Elymus*-dominated sown range has most of its leaves below 25 cm of height, which is not suitable for harvesting by machine. *Elymus* fields are used as grazing land in winter rather than harvested. Because *Elymus*-dominated range is not fertilised frequently, these ranges become degraded after several years, and their potential productivity is not fully realised. The authors suggest that perennial low grass varieties could be cultivated to establish grazing range for winter and spring and that annual fodder, such as oats and legumes, be grown for making hay for supplemental feeding during winter disasters and for fattening livestock in feed lots.

Crop straw utilisation

At present, there are over 133 thousand hectare of crop fields in Qinghai that are comprised of wheat, barley and rapeseed straw. These crop residues could be used as a valuable feed resource and reduce grazing pressure on rangeland. Mechanised equipment will need to be introduced, however, to produce sufficient hay and silage products.

Rangeland Industry System concept as a guide for livestock production

Highly efficient and sustainable development of rangeland resources in Qinghai should depend on a rational rangeland production system. This is extremely important for rangeland development in vulnerable environments. In areas where the nomads are being settled, particular emphasis should be given to both forage quantity and quality, new forage resources, and improvement of rangeland.

Family ranch operations

Family ranch operations are the best practical format for livestock production at present. For Rangeland Industry System to succeed, herders need to be advised on their rangeland and livestock management, to be encouraged to invest in livestock production, and become actively involved in rangeland improvements.

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Production and use of an illustrated handbook for sheep and yak herders in Qinghai

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Summary

Sheep and yak herders in pilot areas of the Qinghai-Tibetan Plateau are targeted by extension activities of the Bureau of Animal Husbandry. The abundance of detailed technical information discussed on field-days requires a reminder. For this purpose a handout was made in the form of a booklet of 190 pages. The booklet has an illustration on each page, and a minimum of explaining text in Tibetan and Chinese languages. This paper discusses features of the booklet and experiences with its testing. The most important feature of the booklet is in its illustrations. Without these, the booklet would be less attractive and less understandable to many herders.

Keywords: Handbook, parasite, sheep, yak

Introduction

Sheep and yak herders on the Qinghai-Tibetan Plateau are targeted by extension activities of the Bureau of Animal Husbandry (BAH) with the main aim being to increase the productivity of their animals. Most of the extension activities comprise the development and dissemination of practical and technical advices. Common messages to herders are: the cultivation of fodder oats in sheep pens (to improve the stock of winter feed); the control of internal and external parasites; and the prevention and control of diseases of young stock (to reduce mortality of lambs and calves).

Herders on the Plateau live far apart, especially in summer when they move their herds and flocks to the upper pastures. Reaching herders for extension activities is costly and time consuming. Contacts of BAH field staffs with herders therefore often concentrate on those who live relatively near to the townships.

To achieve wider coverage for disseminating technical messages, the BAH organises field demonstration days during the winter season, inviting groups of herders to a camp of a nearby herder. An appointed 'herder technician', initially assisted by a staff member of the county's or township's government office, demonstrates the practice or treatment

advocated whereby the host's animals or land is used. On such meetings the merits of a treatment are discussed, and, in case the meeting is a repetition, the effect of an earlier demonstration is reviewed with participants. The same herder technician plays a role in the supply of drugs and seed, which are advocated during the field-days.

To support the abundance of information that is discussed during field-days, an illustrated booklet has been prepared. This paper discusses features of the preparation and use of this booklet. It does not elaborate on the contents of messages and on how these messages were developed.

The paper reviews the use, the strengths and limitations of the pictures in support of written text as a means of communication. They argue that despite the differences in which herders interpret many of the drawings, the booklet in the context of its use, would not be effective without those pictures (Figures 1 and 2). They also describe practical issues of layout and report on the cost for printing 6000 copies.

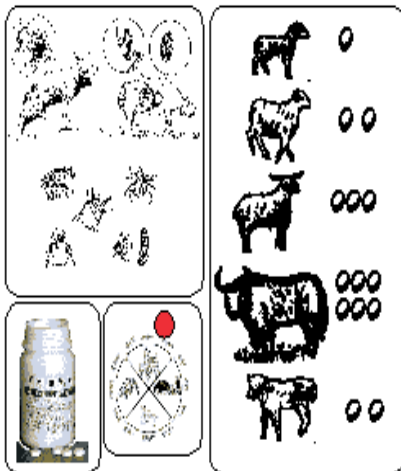


Figure 1. Picture used with 'parasites' topic. (It should relate to the parasites that can be treated using the drug shown, the dosages and the time of treatment.)



Figure 2. Symbol used to indicate seasons. (It is repeated wherever an activity is time-bound.)

Preparation

Definition of the user

A clear picture of the user of the booklet, Tibetan herders (Figure 3), had to be defined first. It is this picture that would influence the form of the booklet. There is a vast and colourful diversity in the background of herders and their ways of communication. We simplified this picture into the following generalisations:

- Herders are Tibetan speaking (thus any text would need to be in Tibetan);
- A majority of herders is unable to read but have family members or close acquaintances who can (the written language had to be colloquial and local terms would need to be

used; illustrations would need to be included in support of text; the booklet would need to be attractive to children);

- Herders have a keen eye in observing animals, the environment and people; they will be interested in illustration of these but at the same time critical illustrations would need to be easy to interpret;
- Herders are more interested in information that relates to their own experiences. The most common problems are: feed scarcity, rodent damage on badly degraded rangeland, the risk of a snow disaster and security/theft (the booklet would need to cover at least some of these aspects).



Figure 3. A herder with a handbook.

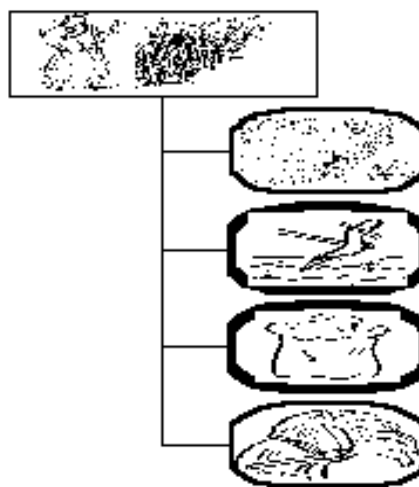


Figure 4. Table of contents for the chapter on cultivating oats.

Definition of the content

The initial themes for the handbook had already been decided on: information about those practices that had been tried out and developed (mostly with selected herder families) by the project in the past three years. These included the cultivation of oats in sheep pens (Figure 4), control of internal and external parasites, and prevention and control of the main diseases in lambs and yak calves.

Only after testing the first draft, which comprised both herders and project staff, were two additional themes added: re-sowing of degraded rangeland and the control of pika (*Ochotona curizoniae*).

Definition of the form

To encourage users to read or have the text read to them, a picture would need to be added to each page of text. The text was to be limited to two or three essential sentences per page in colloquial Tibetan, and its translation in Chinese. Line drawings were chosen for

illustrations, as these reproduce better. Instead of a written table of contents, a 'tree of icons' was made, of which parts were repeated on each page.

Process and cost of production

Technical specialists formulated the content of each chapter. Each message was formulated in two or three essential sentences per page and each page was illustrated with a sketch or contained an idea for a sketch. Two editors ensured cohesion between topics and interfaced with artists who prepared illustrations. On average each drawing was made 1.6 times, before it was finally accepted.

The working language was Chinese. Translation into Tibetan was the last step. The booklet was laid out on a desktop PC using Nitārtha-Sambhota software to produce Tibetan fonts.

The page size of 98 × 135 mm (landscape) allowed the use of standard 16 K paper (folded in four) of 60 g. Only the cover page used 120 g paper and was colour-printed. The number of pages was 190 and the cost of printing (including material) approximated 4.20 RMB Yuan (US\$ 0.55) per copy, for a series of 6000 copies.

Results of testing

A first draft was made in 40 copies and tested with small groups of herders and field staff, in five townships, and reactions were sought through semi-structured interviews.

Interpretations of drawings

When herders and staff were shown illustrations only and were asked to describe the illustrations, most difficulties were encountered with abstracted ideas. These included: the balancing of livestock numbers against feed resources (Figure 5), deficiencies of micro-elements in feed, and timing of activities (Figure 2). Herders looked critically at drawings showing signs of sickness in lambs (Figure 6).

Understanding of the Tibetan text

Many of the herders who could read had difficulties with some parts of the initial text. The most important reactions concerned the use of non-local terms (for instance external parasites) and the use of difficult language, which was sometimes recognised as having been translated from Chinese.

Use of the booklet

After this testing phase, changes were made resulting in the final booklet. Of these, 6000 copies were printed and distributed to county field staff.



Figure 5. Illustrations conveying abstract ideas such as feed balancing and deficiencies of micro-elements were difficult to conceive and understand.

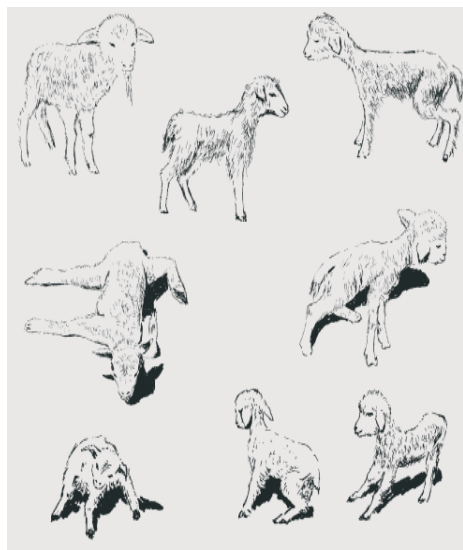


Figure 6. Supposedly sick lambs. Sickesses shown here include the common cold, deficiencies, diarrhoea and general weakness.

Distribution to participants of field-days

The booklet had been intended as a reminder of information discussed during field-days. During campaigns for promoting the cultivation of oats, it was distributed to nearly 1200 herders in 20 townships during the spring of 2000. During these demonstrations, the staff generally referred to the relevant chapters in the booklet. Some staff had prepared additional handouts to supplement the information from the booklet. In general, participants of field-days were very positive of the information supplied in the booklet.

Offer for sale

The booklet has been offered for sale as well, at a subsidised price of 2 RMB Yuan (approximately US\$ 0.25, or 45% of the production cost). Only a few books were sold (less than 5% during the first 6 months). The main reason given for the lack of interest on the part of herders is that in the project area (comprising the poorest townships of Qinghai) herders are not used to paying for information that originates from the government.

Included in a package of sold inputs

A third option for distribution of the booklet has been the optional sale of it to herders when they buy drugs for control of stock diseases and parasites, as well as oats seed. None of the field staff have reported to distribute the booklet.

Discussion

This booklet is a prime example of a mass medium. It contains an abundance of information, gathered and developed by specialists and compressed into a small form. It's strength is that many herder families can have a copy and thus access to information, it's weakness is that the information is one-way, generalised, and on its own probably not effective or convincing. The booklet is therefore targeted for use in connection with field demonstration days, as a reminder after discussions and hands-on experimentation.

The booklet covers a wider scope of topics (oats, parasites, pika control, young stock diseases) than is normally covered in one field-day. Thus, when it is used in conjunction with a field-day, some of the topics will not be discussed and the booklet may be the only source of information the herder has on such topics. This can be both an advantage and a disadvantage. The advantage is that the herder is made aware of additional messages than those covered during a field-day. The disadvantage is that these messages are on themselves hardly enough to convince. The booklet is very valuable as a reminder of dosages for the various drugs that are advocated.

Session II: Genetic diversity

Genetic variation of mitochondrial DNA within domestic yak populations

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Summary

Yak (*Bos grunniens*) are members of the Artiodactyla, family Bovidae, genus *Bos*. Wild yak are first observed at Pleistocene levels of the fossil record. We believed that they, together with the closely related species of *Bos taurus*, *B. indicus* and *Bison bison*, resulted from a rapid radiation of the genus towards the end of the Miocene. Today domestic yak live a fragile existence in a harsh environment. Their fitness for this environment is vital to their survival and to the millions of pastoralists who depend upon them. Their wild counterparts are further marginalised to the most inhospitable areas of the Qinghai-Tibetan Plateau. Recent introduction of cattle (mainly *B. taurus*), in an attempt to improve stock, may threaten the integrity of the yak genetic make-up with the consequence of reducing fitness with respect to cold temperature and high altitude survival. Mitochondrial DNA (mtDNA) is ideally suited as a tool for studying population genetics because it has the unique features of maternal inheritance, a relatively fast rate of evolution and lack of recombination. Population history is traced back through the maternal line, which excludes the male genome and thus establishes a simple underlying pattern. It is possible to investigate the recent history of domestication due to the fast evolutionary rate of mtDNA. Lack of recombination between the mtDNA of yak and cattle is informative for the study of introgression. This paper discusses the genetic diversity of yak expressed in terms of sequence variations found in the displacement loop (D-loop) of mtDNA. A comparison has been made between these values and those found within other domestic species, primarily taurine cattle. An exact time for the domestication of yak is difficult to discern from archaeological data; here we estimate a time based upon a molecular clock of approximately 5000 years ago. Finally we shall feature the mtDNA introgression observed in yak populations.

Keywords: Cattle, introgression, mitochondrial DNA, sequence, variation, yak

Introduction

Bos grunniens, *B. mutus* and *Poephagus mutus* are all species names, which have been assigned to yak. This variety of nomenclature reflects the uncertain relationship of the yak to other members of the Bovidae. The most widely used term is *Bos grunniens* and this will be used here. *B. grunniens* is grouped within a subfamily of the family Bovidae in the order Artiodactyla (even-toed ungulates) (Nowak 1991).

Establishing the phylogenetic position of *B. grunniens* within the Bovidae family has been problematic. Groves 1981 (cited in Janecek et al. 1996) suggested that the two species of bison were most closely related to yak, while alternative phylogenies place the Bison outside a clade containing all species of *Bos*. The recent application of molecular genetics to this field has clarified some, but not all, of these problems. In a cladistic analysis of mitochondrial ribosomal DNA from the family Bovidae, Gatesy et al. (1997) found that only that only in a few cases did the addition of morphological data overturn a clade favoured by the molecular data. Janecek et al. (1996) used the mitochondrial DNA (mtDNA) nucleotide sequence of the cytochrome oxidase II (Cox II) gene to infer phylogenetic relationships among the different taxa of the family Bovidae. They found a monophyletic clade of *Bos/Bison* and that the genus *Bos* is paraphyletic with respect to the genus *Bison*. Unfortunately the yak used in this study was a hybrid. Within the Bovini species it has been proposed that there is a correspondence between genetic distance and geographical origin. For example, yak are grouped closest with *Bison* in a principal co-ordinate analysis of amplified fragment length polymorphisms (AFLP) (Buntjer 1997, cited in Lenstra and Bradley 1999).

Yak inhabit areas of harsh conditions, generally living at altitudes of between 2000 and 5000 metre above sea level (masl). The average annual temperature in yak rearing areas is -8°C with yak being able to withstand temperatures of -40°C in the winter months (Shijan and Weisheng 1997). The average annual rainfall is 350–500 mm (Davaa 1997) and grasses in the area grow for only one-third of the year. Wild yak have no fixed territory and wander in search of food (Shijan and Weisheng 1997). Yak can cover an area of 200–300 km² in search of food. Due to a shortage of grass during the winter, yak only consume an average of 40–60% of their daily fodder requirements. An individual animal can lose as much as 25–30% of its total body weight over the winter months (Davaa 1997).

We believed that *B. grunniens* were first domesticated on the Tibetan Plateau. According to Olsen (1990) the exact period when *B. grunniens* were domesticated is unknown, although archaeological evidence suggests this may have been some 5000 years ago (Cai and Wiener 1995; Ning et al. 1997). Yak are of great social and economic importance. Yak rearing is the major source of income for many nomadic and semi-nomadic people in China, Nepal, Bhutan, India, Pakistan, Mongolia, Russia, Tuva, Buryatia, Kirgizia and Tazakistan. Yak and yak products have a wide range of utility. Yak milk, a valuable source of protein for herders, is also used in the manufacture of cheese. The meat is popular because of its unique

flavour. Yak hair and wool is used to make tents, ropes, bags and clothing. The livestock themselves are used to plough, carry produce and as a form of transport.

Phenotypic characters may help to distinguish different yak in different countries. For example, there are five breeds of yak found in India: Common, Bisionia, Bareback, White and Forehead Long Hair (Pal and Madan 1997). Cheng (1984) identified three types of yak in China: the Valley type, the Plateau Grassland type and the White yak, within these three types a number of breeds can be distinguished. As with European cattle certain breeds have been developed for particular traits. Common yak are most suitable for milk production while Bareback varieties should be used for meat. Brown yak tend to have finer undercoats and should be used for wool production (Pal and Madan 1997). Chinese yak, both white and black, are renowned for good quality meat with a distinctive flavour (Cheng 1984).

It has been proposed that yak breeding programmes will improve milk yields, meat quality, draft power, and wool productivity. Inbreeding remains a major obstacle for yak herders due to the difficulty of movement in these high altitude regions (Pal and Madan 1997). In an attempt to improve yak stock, programmes of hybridisation with cattle have taken place. Such programmes yield considerable benefits in production and may actually date back more than 3000 years (Shijan and Weisheng 1997). This approach has been treated with caution by those who are concerned that this may lead to a deterioration of the yak gene pool, which could result in a loss of fitness with respect to the cold temperature and high altitude survival (Tshering et al. 1997). Studies have demonstrated the advantage of mating wild and domestic yak (Shijan and Weisheng 1997). Such programmes pose little threat to the yak gene pool but may result in the production of some intractable animals.

Population genetic studies

A number of techniques have been used to study genetic diversity and molecular phylogeny. These include the assaying of protein polymorphism by protein immunology and protein electrophoresis, DNA hybridisation studies, restriction digests, repetitive DNA (e.g. microsatellites) and DNA sequencing of both nuclear and organelle DNA.

Mitochondria are organelles found within the cell. They are the sites for energy production during aerobic respiration. Each mammalian mitochondrion contains its own DNA, in the form of a covalently closed circular double stranded DNA molecule that contains 13 protein-coding genes, 2 ribosomal RNA (rRNA) genes and 22 transfer RNA (tRNA) genes (Gray 1989).

A number of characteristics make mtDNA a useful genetic marker; these include maternal inheritance, lack of recombination and fast rate of evolution.

No evidence for recombination has been found in interspecific hybrid cell lines (Clayton and Schadel 1997). Sperm mitochondria can enter the egg (Strauss 1999) but Avise (1991) thought that the absence of paternal mtDNA in the offspring is the result of an active mechanism in the oocyte, which removes paternal mtDNA.

MtDNA has a very rapid evolutionary rate. The rate of evolution of the mtDNA is different for different parts of the molecule. The tRNA and rRNA genes evolve approximately 100-fold quicker than their nuclear counterparts (Brown 1985; Avise 1991).

The non-coding displacement loop (D-loop) evolves 5-times faster than the rest of the mtDNA. The silent site substitution rate in mammalian mtDNA has been estimated at 4.7×10^{-8} per site/year, i.e. 10-times higher than the rate for nuclear pseudogenes (Awise 1991).

A striking feature of mtDNA evolution is the ratio of transition substitutions to transversion substitutions, which is approximately 10:1 for the overall molecule (Gray 1989). This ratio is even more prominent in the D-loop where Bradley et al. (1996) observed a ratio of 57:1 for domestic cattle and the ratio for domestic yak was estimated at 36:1 (Bailey et al. in preparation). The ratio decreases as the divergence time increases due to multiple transitions at the same site. Explanations for the rapid rate of mitochondrial evolution include inefficiency of the repair mechanism (Cullinane and Bohr 1998) and relaxed functional constraint, partly due to the fact that mtDNA does not encode the proteins involved in its own replication, transcription and translation (Awise 1991). Other possible mechanisms are a high rate of turnover of mtDNA, a high exposure to oxidative damage and a relative lack of a recombinatorial mechanism (Awise 1991). It has also been suggested that mtDNA evolves more quickly than nuclear DNA due to a lack of associated histone proteins to the mtDNA (Gillespie 1986).

The D-loop region is non-coding and is involved in the control of replication and transcription (Clayton 1991). It is located between the tRNA genes for proline and phenylalanine. This region has been examined for nucleotide diversity and typed for some RFLP sites (Bailey et al. in preparation).

MtDNA patterns in domestic livestock

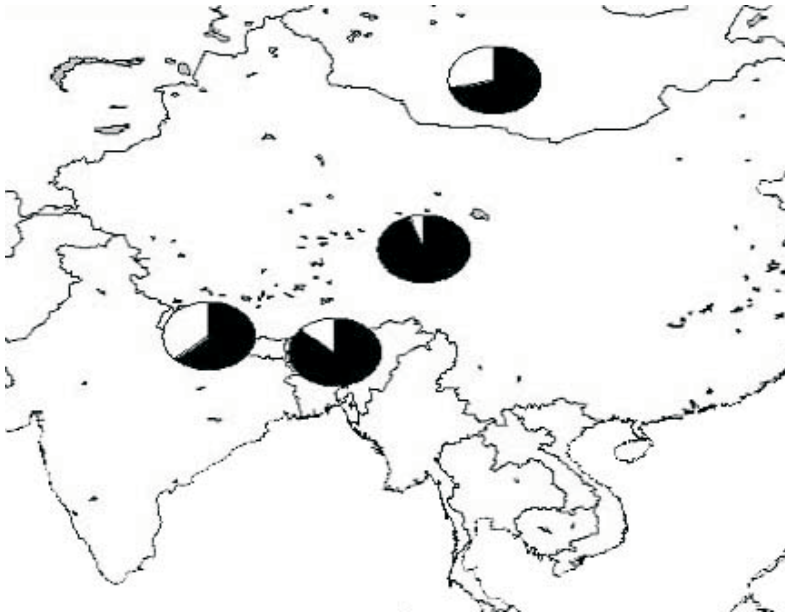
Bradley (2000) identified a classic 'double-headed broomstick' topology in an analysis of mtDNA sequence divergence for the four domestic ungulates: cattle, sheep, water buffalo and pig. In each case the mtDNA clusters into two distinct and divergent groups. The clusters are also geographically distributed and he argued that this pattern is indicative of a dual domestication pattern. Loftus et al. (1994) first noted a geographically distinct mtDNA clusters in cattle. One of their clades contained all the Indian cattle sequences, while the other contained African and European cattle sequences. They concluded that two separate domestication expansion events had occurred approximately 10 thousand years ago each from a highly divergent lineage, which separated approximately 0.2 to 1 MYA. The pattern of the domestic yak populations, taken from China, Bhutan, Nepal and Mongolia, is also a double-headed broomstick (Bailey et al. in preparation). This suggests that yak have undergone a domestication process similar to other ungulates. This dual domestication pattern differs from the pattern detected in other domesticates, such as horse and dog, which are known to have multiple domestication events.

The domestication of *B. grunniens*

Bradley (2000) noted that in most of the domestic populations a geographical distribution of haplogroups is observed. There are some exceptions to this observation: for example

sheep. It has been suggested that secondary mixing has occurred in sheep populations because these animals are easily transported and may have been preferentially used in trade.

In yak mtDNA, two divergent haplogroups can be identified— Y1 and Y2. There does not appear to be a significant difference between the Chinese, Bhutanese, Nepalese and Mongolian yak (Bailey et al. in preparation). Yak have been referred to as the ‘ships of the plateau’ (Wenxiu 1997) and movement across the mountainous regions is only possible using yak. Such movements could act to reduce the amount of geographical partitioning observed, resulting in the pattern observed in Figure 1.



Data: Bailey et al. (in preparation).

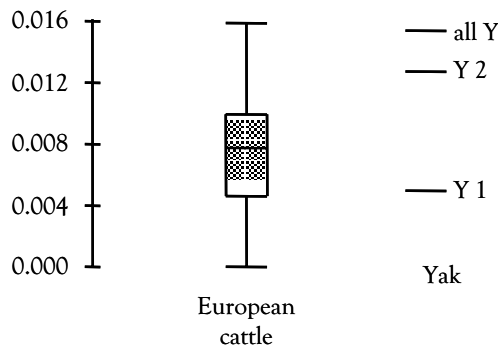
Figure 1. A distribution map of the Y1 and Y2 haplogroups in samples from China, Bhutan, Nepal and Mongolia, where the shaded area of the pie is Y1 and the non-shaded area is Y2.

Molecular estimated dates for yak domestication, based on a molecular clock and subject to large errors, are roughly comparable to known archaeological data, which suggest a putative domestication date approximately 5000 years ago (Bailey et al. in preparation).

Comparison of mtDNA genetic diversities between European *B. taurus* and Asian *B. grunniens*

Nucleotide diversity values have been calculated for both the haplogroups Y1 and Y2 and for all Y (both 1 and 2). Diversity values can differ dramatically between domestic and wild populations. Therefore it is valuable to make a comparison between the nucleotide diversities found in yak and those found in another domestic species. Figure 2 is a comparison of the control region nucleotide diversities of the yak population and a box plot

of the values found in 19 European cattle breeds. It clearly shows that the variability found in yak is of the same order as that found in European cattle. The similarity of diversity levels reflects the domestic history of these species. The total nucleotide variation, for both yak haplogroups, is highest because it reflects the whole mtDNA domestic pool from both centres of domestication. The Y2 is only based on a small number of individuals and is subject to change with future studies. The nucleotide diversity for Y1 is slightly lower than the median value for cattle. This relationship reflects the relatively recent domestication of yak approximately 5 thousand years ago as compared with the domestication of cattle (estimated to be as long as 10 thousand years ago).



Data: Bailey et al. (in preparation). A boxplot of distribution of nucleotide diversities for 19 extant European breeds (MacHugh et al. 1999) is provided for comparison. Where the length of the box is interquartile range of the European nucleotide diversity and the horizontal line within it the median. The vertical lines outside the box extend to the smallest and largest observations and the shaded region the standard deviation.

Figure 2. Yak control region nucleotide diversities of all sequences studied and for the individual haplogroups Y1, Y2.

Bailey et al. (in preparation) note that some haplotypes are shared between animals from different populations. Investigations of mtDNA haplotypes by RFLP analysis (Jianlin 1997; Tu et al. 1998) also indicate that mtDNA haplotypes are shared across different Chinese yak breeds. Similarly, Tu et al. (1996) found that there were no significant genetic differences among the various yak populations in China at the level of protein polymorphism. Interestingly, haplotypes sharing across breeds and country groups is also observed within European cattle (Loftus et al. 1994; Bailey et al. 1996; Bradley et al. 1996).

MtDNA is not a useful tool for investigating domestic animals at the breed level because of the haplotype sharing between breeds for example as observed in both European cattle and yak populations. It would therefore be misguided to base yak breeding programmes on mtDNA surveys without additional knowledge of nuclear DNA. When microsatellite studies were made of 20 loci in European cattle it then became possible to observe resolution at the level of the breed (MacHugh et al. 1998). A similar study of both autosomal and sex linked microsatellites in yak should yield genetic structuring at the breed level. Such a study would be very informative for assisting with future breeding programmes.

Less than 1% cattle mtDNA was observed in a survey of yak mtDNA types (Bailey et al. in preparation). Whilst this is encouraging for those who are concerned about the effects of introgression (hybridisation with cattle) on yak it is important to note that mtDNA can remain unperturbed even when high levels of introgression are observed at the nuclear level (MacHugh 1997). It is therefore essential that a microsatellite study be conducted to allow assessment of introgression and facilitate yak-breeding programmes.

In summary the genetic investigation of yak mtDNA reveals a pattern consistent with other domestic ungulate species and suggests a dual domestication of these animals. The lack of phylogeographic distribution between yak populations is similar to the situation observed in sheep and probably reflects the mobile nature of yak. The genetic diversity observed in *B. grunniens* populations is comparable to levels found in European cattle populations. MtDNA is useful for examining the history of domestication within ungulate populations. It is essential to examine yak microsatellite markers to study the genetic integrity at the level of the breed.

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Low level of cattle introgression in yak populations from Bhutan and China: Evidences from Y-specific microsatellites and mitochondrial DNA markers

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Summary

We have used three cattle Y-specific microsatellite loci (Edwards et al. 2000) and a mitochondrial DNA (mtDNA) specific marker (Ward et al. 1999) to assess the level of cattle introgression within one Bhutanese and four Chinese yak populations. Successful PCR amplifications both in female and male yak were obtained with microsatellite INRA126. Microsatellites BM861 and INRA189 were Y-specific in both cattle and yak with the presence of *Bos taurus*, *B. indicus* and *B. grunniens* diagnostic alleles. Moreover, marker INRA189 was shown to be polymorphic in yak with three alleles. Only one yak male (Gannan yak) had taurine cattle Y chromosome. Mitochondrial DNA (mtDNA) multiplex PCR reactions allowed us to assess the level of female cattle introgression. We only detected three female yak with a cattle mitochondrial DNA out of a total of 239 animals, one female in the Bhutanese and two females in the Tianzhu White yak population. Our results indicate that within the five yak populations studied the level of cattle introgression originating from the initial F₁ crossbreeding female cattle with male yak is low.

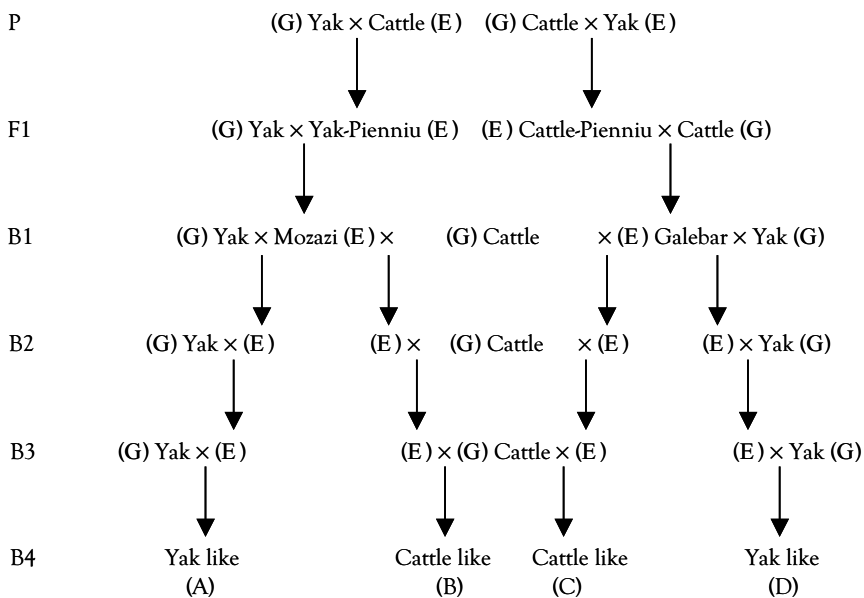
Keywords: Cattle, diversity, introgression, microsatellite, mitochondrial DNA, yak

Introduction

The yak (*B. grunniens*) and the cattle (*B. taurus*) are two separate species belonging to the same genus included within the family Bovidae. However, reproductive isolation between the two species is incomplete with the hybrids F₁ female fertile and the hybrid F₁ male sterile. Crossbreed males will only be fertile after the third generation (B₃, Figure 1) of backcross with yak or cattle. F₁ hybridisation between the two species is commonly practised as a very efficient way to improve the milk and meat production in intermediate altitudes (1000–3000 metres above sea level).

The hybridisation of yak with *B. taurus* cattle in China can be traced back to 3000 years ago. According to written history, the ancient Qiang people started to practise hybridisation of yak with cattle during the Yin Dynasty (approximately 1100 B.C.) (Cai 1990). Additionally, it is thought that Wencheng, the Princess of Tang Dynasty, brought some Chinese *B. taurus* cattle to Tibet when she married Srong-Brtzan-Sgam-Po, the King of Tibet, in 641 A.D. (Zhang 1989).

The nomenclature of hybrids (yak × cattle crosses) is relatively complex and often the same cross will have different names in different regions or countries. There are two ways to produce hybrids (Figure 1). However, the desired F₁ crossbreed will be more often obtained through the crossing of male cattle with female yak. Subsequent backcrossings are not very popular amongst farmers.



Redrawing according to Zhao Zenrong 1957, cited in Cai 1990; A and D show the two patterns of backcrossed hybridisation most frequently practised. The phenotypic appearance of B₄ yak backcrosses in lineage A and D will often be indistinguishable from the parental yak. Similarly, the phenotypic appearance of B₄ cattle backcrosses in lineage B and C will often be indistinguishable from the parental cattle. Lineage A and B will have a cattle mitochondrial DNA genome. Lineage C and D will have a yak mitochondrial DNA genome. Cattle introgression in lineage D and yak introgression in lineage B will only be detected using autosomal specific markers with cattle or yak diagnostic alleles.

Figure 1. Hybridisation patterns of yak with *Bos taurus* cattle.

Intensive crossbreeding of yak with *B. taurus* cattle was first practised in China with cattle imported from The Netherlands in Xikang of Sichuan Province in the late 1930s by Prof Chen Zhichang, the pioneer in the field of animal science in China, but the programme was later abandoned for unknown reasons (Zhang 1989). Shortly after the foundation of People’s Republic of China in 1949, similar large hybridisations breeding schemes were carried out in Qinghai, Sichuan, Gansu and Tibet. However, currently the crossbreeding of yak with cattle is not practised intensively in China in a controlled way.

To estimate the level of cattle introgression in today's yak populations of China and Bhutan, we used three cattle *Y*-specific microsatellite loci (Edwards et al. 2000) and one mitochondrial DNA (mtDNA) typing system (Ward et al. 1999) in four Chinese and one Bhutanese yak populations.

Materials and methods

Yak populations and control samples

One Bhutanese (BHU) and four Chinese yak populations (Gannan yak (GY) in Luqu County, Tianzhu Black yak (TBY) in Tianzhu County, Tianzhu White yak (TWY) in the Tianzhu White yak Breeding Farm of Gansu Province, and a crossbreed of domestic yak with wild yak (QY) in the Datong Yak Farm of Qinghai Province) were studied. For mitochondrial DNA analysis two DNA samples were used as a positive control: a male F_1 N'Dama \times Kenyan Boran cross and a Siri cattle *B. taurus* sample both having a taurine mitochondrial DNA genome. For *Y*-specific microsatellite analysis only one positive control was used (a F_1 N'Dama \times Kenyan Boran cross with a *B. indicus* *Y*-chromosome). Information regarding the size of the *Y*-specific taurine and indicine alleles were obtained from Edwards et al. (2000) after correction to take into account the differences in allele size calling methods between the two studies.

Total genomic DNA extraction

Total genomic DNA was extracted from blood, following either the method of Sambrook et al. (1989) or the salting-out procedure of Montgomery and Sise (1990).

Mitochondrial DNA analysis

The control region cattle specific primers (mtD1: 5'-AGC TAA CAT AAC ACG CCC ATA C-3' and mtD2: 5'-CCT GAA GAA AGA ACC AGA TGC-3') were used in a multiplex PCR reactions with the highly conserved primers located on the 16S rRNA gene (mtR1: 5'-CCC GCC TGT TTA TCA AAA ACA T-3' and mtR2: 5'-CCC TCC GGT TTG AAC TCA GAT -3'). PCR amplifications were performed in 15 μ l containing 60–80 ng of DNA, 10 pmol of each primer, 0.5 units of *Taq* polymerase (Promega), 0.15 mM of each dNTP (Amersham), 1 \times PCR buffer (10 mM Tris-HCl, pH 8.3) including 50 mM KCl, 0.001% gelatin (Sigma), 0.25% Nonidet P40 (BHD) and 1.3 mM MgCl₂. The amplification programme—performed on a GeneAmp (Applied Biosystems) 9700 thermal cycler—was an initial denaturation step at 95°C for 3 min, then 30 cycles at 94°C for 30 sec, 55°C for 1 min and 74°C for 1 min. A final extension step at 74°C for 10 min was adopted for all amplifications. PCR products were analysed on 1.5% (w/v) ethidium bromide stained agarose gel for 1 hour at 150V in a 1 \times TBE buffer. Results were viewed on a UV transilluminator and a photograph of the gel was taken using a Polaroid system camera (Kodak).

Two hundred thirty nine successful mitochondrial amplifications were obtained (GY, No. = 34; QY, No. = 53; TWY, No. = 59; TBY, No. = 33; and BHU, No. = 60).

Y-specific microsatellites amplification

Primer DNA sequences for INRA126, INRA189, BM861 can be found in Edwards et al. (2000). PCR amplifications for Y-specific primers were performed in 10 μ l containing 20–35 ng of DNA, 5 pmol of each primer, 1 unit of *Taq* polymerase (Promega), 0.125 mM of each dNTP (Amersham), 1 \times PCR buffer (10 mM Tris-HCl, pH 8.3) including 50 mM KCl, 0.001% gelatin (Sigma), 0.25% Nonidet P40 (BHD) and 2 mM MgCl₂. The amplification programme—performed on a GeneAmp (Applied Biosystems) 9700 thermal cycler—was an initial denaturation step at 95°C for 3 min, then 30 cycles at 95°C for 30 sec, x°C for 1 min, (where x = 55–61°C), INRA126 = 55°C, INRA189, = 58°C, BM861 and 72°C for 1 min. A final extension step at 72°C for 7 min was adopted for all amplifications. PCR products were analysed on a 5% denaturing polyacrylamide gel using an ABI377 DNA sequencer and the internal size standard GENESCAN 350-TAMRA. Data were collected and analysed with the ABI Prism™ 377 (version 2.1) and GeneScan™ 672 (version 3.1) softwares. The third order least square method was used for size calling. Results were analysed using the Genotyper™ (version 2.0) software.

Data were obtained for 78 male and female samples for INRA126 (BHU, No. = 8; GY, No. = 28; and QY, No. = 42), 82 males for BM861 (GY, No. = 27; QY, No. = 23; TWY, No. = 6; TBY, No. = 2; and BHU, No. = 24) and 83 males for INRA189 (GY, No. = 29; QY, No. = 26; TWY, No. = 4; TBY, No. = 2; and BY, No. = 22).

Results and discussion

Cattle male introgression within yak populations

One Y-specific cattle microsatellite, INRA126, was successfully amplified in both male and female yak (No. = 78). It confirms the previous observation by Edwards et al. (2000), based on six female yak samples, that this locus Y-specific in cattle is not Y-specific in yak. We observed two size alleles with all animals being monomorphic, a 182 bp allele in 77 animals and a 184 bp allele in one male yak (GY 31), the later being an allele of taurine origin (Edwards et al. 2000). It is possible that the yak X-chromosome has retained a homologous sequence to the Y chromosomal segment containing the INRA126 microsatellites (Edwards et al. 2000). However, it should be noted that in no animals we observed two alleles not even in the male yak showing the Y-cattle specific allele.

Microsatellites BM861 and INRA189 were both Y-specific in cattle and yak with *B. taurus*, *B. indicus* and *B. grunniens* diagnostic alleles. BM861 amplifies two different size alleles, 149 bp in 81 males (yak diagnostic allele) and a 159 bp (taurine diagnostic allele) in a unique male (GY 31), the same animal showing an allele of taurine origin at INRA126. Similarly, only one male, again GY 31, had a taurine Y-specific allele of 92 bp at INRA189.

The other 82 males showing large size alleles (see below). The mtDNA of GY 31 is of yak's origin (data not shown).

The observation that one male yak had a cattle Y-chromosome was unexpected. Indeed the male F₁ progeny between yak and cattle are known to be sterile. Most likely F₁ males are present in the Gannan population and this male was sampled by mistake.

INRA189 is polymorphic in yak. Excluding the 92 bp taurine specific allele, we observed three other alleles of 98, 100 and 102 bp length (Figure 2). The frequencies of these alleles vary between yak populations. Only one allele (98 bp) is observed in the two males analysed of the Tianzhu Black yak (TBY), but at least two alleles are observed in the four other yak populations studied. The most common allele in the Bhutanese yak (21 males out of 22) is the 98 bp. On the contrary, the most common allele in the Gannan yak (21 males out of 29) and the Tianzhu White yak (3 males out of 4) is the 100 bp. The crossbreed population (QY) from three wild yak bulls with domestic female yak is the only one showing three alleles including the 102 bp allele not observed in any other populations. It supports that we may find in wild yak, genetic variation absent from domestic populations of yak.

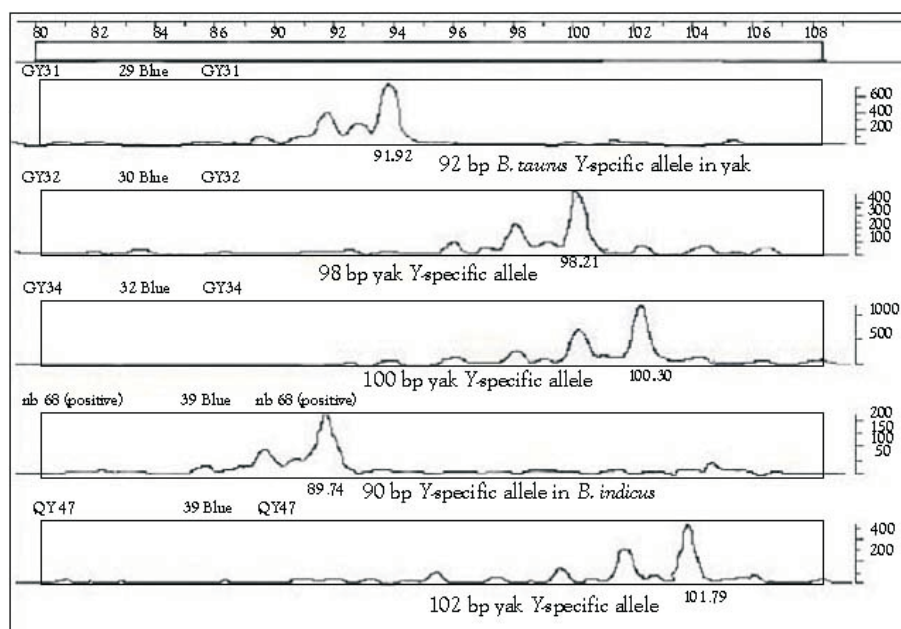


Figure 2. Allelic variation observed at the Y-specific microsatellite INRA189.

Cattle female introgression within yak populations

The results of the multiplex mtDNA PCR amplification of one Siri cattle, one N'Dama × Kenyan Boran cross and six yak samples are shown in Figure 3. The 16S band is present in both yak and cattle and it is used as an internal control. The PCR primer pair used to amplify the 357 bp of the mtDNA control region band is specific of cattle mtDNA (Ward et al. 1999) and it will not amplify the yak' mitochondrial DNA. Amongst 239 successful amplifications, only one female in the Bhutanese population (BHU) and two females in the

Tianzhu White yak (TWY) populations have a cattle mtDNA. Following the possible crossbreeding schemes as described in Figure 1, these three animals would have inherited a cattle mitochondrial DNA through the A lineage with an initial crossbreeding with a female cattle (Figure 1).

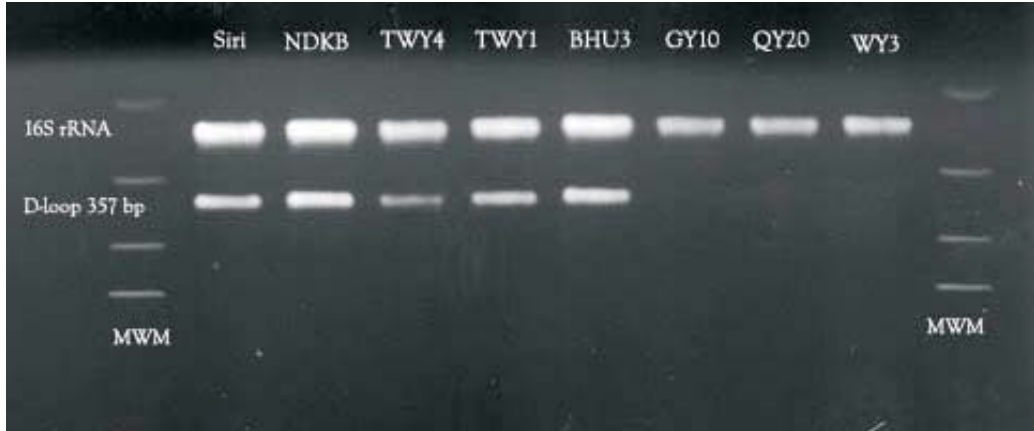


Figure 3. Results of a multiplex mtDNA PCR amplification from one Siri cattle, one Gambian N'Dama × Kenyan Boran cross (NDKB), and 6 yak samples (TWY4, TWY1, BHU3, GY10, QY20, BHU7) using cattle mtDNA control region specific primers and 16S rRNA primers known to amplify both in yak and cattle (World et al. 1999). Samples with the 357bp length fragment of the mtDNA control region have the cattle mtDNA haplotype. It is detected in three yarks (TWY4, TWY1, BHU3).

Only one male (Gannan yak population) out of 82 to 83 males analysed had a cattle taurine Y-chromosome. It is not surprising, as the F_1 crossbreed male cattle × female yak is known to be sterile. Our results suggest that a F_1 male has been sampled by mistake in the Gannan herd. Interestingly, INRA189 is polymorphic in yak with at least three alleles. Further studies using a large number of populations and animals should clarify the geographic distribution and frequency of these alleles and may identify others.

Closing remarks

Our study using cattle diagnostic mitochondrial DNA marker indicates that cattle introgression through the female lineages is either absent or low in the five yak populations studied. Indeed, out of 239 animals, only one female in the Bhutanese populations (BHU) and two females in the Tianzhu White yak (TWY) have the cattle mtDNA. However, as these results do not take into account possible cattle introgression through the male lineage (Figure 1, lineage D), it is possible that we are underestimating the level of cattle introgression in the populations. Such pattern of cattle introgression will only be detected using autosomal markers showing cattle diagnostic allele(s).

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Genetic diversity in Bhutanese yak (*Bos grunniens*) populations using microsatellite markers

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Summary

Eight cattle microsatellite markers were used for genetic analyses of three Bhutanese yak (*B. grunniens*) populations (western, central and eastern). There was substantial genetic variability within yak populations, with average heterozygosity range of 0.644 to 0.680. Neighbour-joining tree constructed from Nei's standard genetic distances (D_s ; Nei 1972) grouped western and central Bhutan yak in one clade ($D_s = 0.01$) separate from eastern Bhutan yak ($D_s = 0.20$ and 0.27 , respectively). The genetic distances between the yak from eastern Bhutan and the other two regions suggest that the populations have been separated for at least 4000 years and that they have exchanged <2 migrants per generation. Based on these results, Bhutanese yak populations are categorised into two types: 1) western and central Bhutan yak, and 2) eastern Bhutan yak. Implications of these findings on yak conservation and breeding programmes are discussed.

Keywords: Bhutan, conservation, genetic distance, genetic diversity, heterozygosity, yak

Introduction

Knowledge of the genetic relationships among breeds or populations of yak will be useful in planning for conservation of yak genetic resources, in designing breed comparison experiments and in predicting heterosis in crosses between breeds (Cai and Wiener 1995). Populations, which are genetically very different, should be considered for separate conservation. The genetic relationships among populations can be estimated from gene frequencies at microsatellite loci. The aim of this paper was to assess the genetic diversity within Bhutanese yak populations.

Materials and methods

A total of 169 yak were sampled from three yak populations (western Bhutan 106, central Bhutan 32 and eastern Bhutan 31). No more than one-tenth of each herd or village population was sampled to ensure that the animals sampled were as far as possible unrelated. The eight cattle microsatellite loci studied were TGLA53, TGLA122, TGLA73, AGLA293, BM2113, BM1824, CSSM066 and ETH3. PCR amplification was performed on an OmniGene Thermal Cycler (Hybaid, UK). The number of alleles per loci, observed heterozygosity (H_o) and the unbiased estimates of heterozygosity (H_e) were estimated using computer package Biosys-1 (Swofford and Selander 1989). Dendrogram was constructed using the neighbour-joining (NJ) method (Saitou and Nei 1987). Nei's standard distances (D_s ; Nei 1972), observed heterozygosity (H_o) and expected heterozygosity (H_e), neighbour-joining trees and bootstrap values were computed using the computer package DISPAN (Ota 1993). The software MICROSAT version 1.4 (Minch 1996) was utilised for estimating fixation index (F_{st}) of Reynolds et al. (1983). From simulation studies, D_A (revised Nei's genetic distance; Nei et al. 1983) has been shown to be superior for clarifying the evolutionary relationship of closely related populations, however, D_s was more appropriate for estimating evolutionary time (Takezaki and Nei 1996). As in the present data set there was no apparent difference in the tree topology obtained by D_A and D_s , only the standard genetic distance of Nei (1972), was used. Approximate divergence time between yak populations was estimated by substituting distance values in the equation, $D_s = 2at$ (Nei 1976), where t is the time of divergence between populations and a is the mutation rate. The value of a was assumed to be $1.1 \pm 0.5 \times 10^{-4}$ as derived by Crawford and Cuthbertson (1996) for microsatellite loci in sheep. The number of effective migrants per generation (N_m) was calculated from the equation $E(F_{st}) = 1/(1 + 4N_m)$ (Reynolds et al. 1983).

Results

Genetic variability parameters are presented in Table 1. There was no significant difference in the mean number of alleles per locus among the three yak populations. Similarly, the heterozygosity values among yak populations were not significantly different.

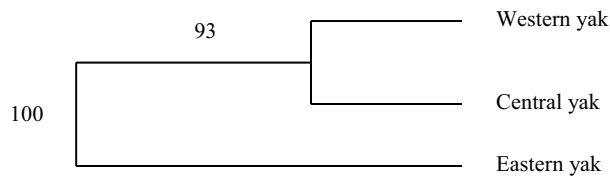
Table 1. Genetic variability parameters in yak populations.

Populations	MNA	SE	Mean heterozygosity			
			H_o	SE	H_e	SE
Western region yak	7.6	1.1	0.621	0.052	0.674	0.053
Central region yak	6.1	0.8	0.598	0.042	0.680	0.051
Eastern region yak	4.8	0.6	0.601	0.069	0.644	0.044

MNA = Mean number of alleles per loci; SE = standard error; H_o = observed heterozygosity; H_e = expected heterozygosity (Nei 1987).

The genetic distance (D_s) values were 0.017 (SE: 0.009), 0.20 (SE: 0.04) and 0.27 (SE: 0.08) between western and central, western and eastern, and central and eastern

populations, respectively. The F_{st} values were 0.013 (SE: 0.005), 0.09 (SE: 0.018) and 0.11 (SE: 0.03) between western and central, western and eastern, and central and eastern populations, respectively. The dendrogram in Figure 1 supports the divergence of eastern Bhutan yak from other two populations with a bootstrap value of 93%. The divergence of western and central region yak occurred comparatively more recently (<1000 years ago) while eastern Bhutan yak population have diverged from western and central populations of yak between 4000 and 16,000 years ago, respectively. N_m estimates as 1.8, 2.5 and 19 between eastern and central, eastern and western, and western and central yak populations, respectively.



Figures at the nodes are bootstrap values of 1000 resampling with replacement.

Figure 1. Neighbour-joining tree of yak populations based on D_s .

Discussion

The mean number of alleles per loci and heterozygosity values were not significantly different among the three yak populations. The high heterozygosity values indicate that inbreeding may not be a problem at the population level. However, observed heterozygosity was always lower than the expected ones (Table 1). It could be due to population subdivision in each region, local inbreeding or the presence of null alleles. Population subdivision can occur because of the geographical isolation of yak herds. The rugged topography and mountain barriers limit movement of yak and impose reproductive isolation. The local inbreeding might be enhanced by the dominance behaviour of the yak bull that prevents other bulls from mating (Steane 1997; Wiener 1997). Furthermore, we conceived that non-amplifying alleles might be segregating at some of the loci as all the microsatellites used were isolated in cattle *B taurus*.

The most striking result is the higher genetic distance values, which separate the eastern region yak from the western and central yak populations. Oral history mentions that the origin of eastern region herders could be traced to Tibet. Evidences from this study suggest that the eastern Bhutan yak population have diverged from the western and central populations of yak between 4000 and 16,000 years ago. If correct, the eastern yak population would have diverged from the other yak populations before or around the time

of domestication. Alternatively, eastern region yak might have incorporated genes from geographically distinct strains of wild yak populations or through hybridisation with local cattle.

A common origin in Tibet could explain the close genetic similarity observed between the central and western yak populations. Also, it could be explained by genetic admixture following migration of individuals from one population to the other.

Closing remarks

We can categorise Bhutan's yak population into two groups. Western and central region yak could be considered as single population, distinct from the eastern Bhutan yak. This result is important for developing a strategy for conservation purposes or designing a breeding programme. The eastern region yak represent a unique gene pool and therefore a separate conservation policy is needed. The differences in genetic distances indicate that significant heterosis may not be achieved from the current practice of crossing between central and western region yak.

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Introgression makes yak populations genetically different: Evidence from Beta-lactoglobulin variations

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Summary

To investigate genetic variation and differentiation in Chinese yak (*Bos grunniens*) populations, polymorphism at the β -Lactoglobulin (β -Lg) locus was examined in 608 yak milk samples, from six geographically isolated areas in Gansu Province, 39 milk samples of yak \times cattle F_1 hybrids and 24 milk samples of *B. taurus* cattle. Polyacrylamide gel electrophoresis detected six genotypes (AA, AB, AE, BB, BE and EE) and three alleles. The commonest allele in yak was allele E which frequency ranged from 1.00 (Tianzhu White yak) to 0.8049 (Xiahe yak). It is absent from cattle. The highest frequency at allele B, 0.1829, was observed in Xiahe yak. It is the commonest allele in the two cattle populations examined. Allele A was present in only two yak populations at very low frequency, 0.0068 (Luqu yak) and 0.0122 (Xiahe yak). Average genetic diversity within individual yak population (H_S) and within the combined total yak population (H_T) was 4.8% and 5.2%, respectively. Average genetic differentiation (G_{st}) between yak populations was 8.4%. We assume that the presence of alleles A and B at the β -Lactoglobulin (β -Lg) locus in yak populations are the results of cattle introgression.

Keywords: Cattle, polyacrylamide gel electrophoresis, hybrid, milk, protein polymorphism, yak

Introduction

The yak (*Bos grunniens*) is a unique animal, native to central Asian highland Himalayas, well adapted to the cold and high altitude environment. It is well known that domestic yak represent an important genetic resource for a large human population dwelling on the Himalayas, the Qinghai-Tibetan Plateau and other yak-rearing countries and areas neighbouring the Himalayas. At present, the estimated numbers of yak are over 14 million, of which more than 90% are found in China (Cai and Wiener 1995).

In dairy cattle, milk protein genes have been widely used as markers for increasing milk yield, altering milk composition and improving the physico-chemical properties of milk for

the manufacture of various dairy products (Ng-Kawi-Hang 1998). Grosclaude et al. (1976a, b) were done studies on yak as early as 1976, studying milk protein variants in Nepalese yak. So far, four yak specific milk protein variants (β -Lg^E, α_{s1} -Cn^E, α_{s2} -Cn^C and κ -Cn^X) have been characterised (Grosclaude et al. 1976a, b, 1982; Mahé and Grosclaude 1982; Kawamoto et al. 1992). In this study, we used yak β -Lactoglobulin (β -Lg) variants as a genetic marker to investigate the genetic variation within Chinese yak populations, differentiation between yak population and the level of cattle introgression in Chinese yak populations.

Materials and methods

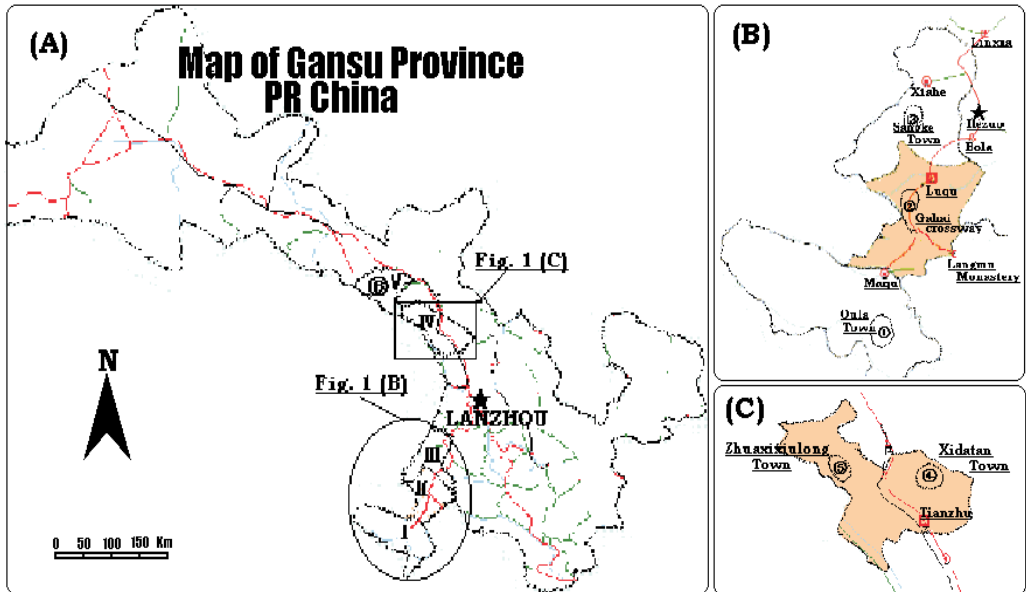
A total of 608 yak milk samples from six geographically isolated areas in Gansu Province were analysed. In addition 24 cattle (*B. taurus*) milk samples and 39 yak-cattle F₁ hybrid milk samples were used as controls. The origin and number of milk samples examined in this study are listed in Table 1. Figure 1 shows the main distribution of yak in Gansu Province and it indicates the locations of the sampled populations.

Table 1. Populations sampled, origins and numbers (no.).

Populations		Origins	No.
Yak	Maqu yak (MQ)	Oula township, Maqu County	190
	Luqu yak (LQ)	Along the provincial roads, Luqu County	235
	Xiahe yak (XH)	Sangke township, Xiahe County	45
	Tianzhu White yak (TZW)	Xidatan township, Tianzhu County	21
	Tianzhu Black yak (TZB)	Zhuaxixiulong township, Tianzhu County	108
	Sunan yak (SN)	Huangcheng Sheep Farm, Sunan County	9
Cattle	Qingchuan cattle (QC)	The vicinity of Linxia County	10
	China Holstein (CH)	Dairy Farm of Gansu Agricultural University	14
Hybrid	Yak \times CH (F ₁)	Datong Yak Farm, Qinghai Province	35
	Yak \times local cattle (F ₁)	Oula township, Maqu County	4

Preparation of whey protein samples and genotyping of β -Lg variants

Ten ml of middle-fresh milk from each animal was collected during the morning milking, frozen into liquid nitrogen and brought back to the laboratory for processing. Skimmed milk was prepared by centrifuging the milk samples at 1500 rpm for 15 minutes at room temperature, the upper milk fat was removed and the lower skimmed milk phase was kept at -20°C . The whey was separated using the acid precipitation method (Tsuji and Togamura 1987). The β -Lg variants were examined by discontinuous electrophoresis using a thin layer polyacrylamide gel system according to Erhardt (1993).



Note: (A) The main yak-rearing counties of Maqu, Luqu, Xiahe, Tianzhu and Sunan are represented as I, II, III, IV and V, respectively, where 1, 2, 3 in (B), 4, 5 in (C) and 6 in (A) show the detailed sampling sites for Maqu (MQ), Luqu (LQ), Xiahe (XH), Tianzhu White (TZW), Tianzhu Black (TZB) and Sunan (SN) yak, respectively.

Figure 1. Distribution of yak in Gansu Province.

Population genetic analysis

The values of H_S , average gene diversity within populations, and H_T , gene diversity in the combined yak populations, were calculated using GENEPOP (version 3.1). D_{ST} , average gene diversity between populations, and G_{ST} , relative magnitude of gene differentiation between populations, are defined as: $D_{ST} = H_T - H_S$ and $G_{ST} = D_{ST}/H_T$, respectively (Nei 1987).

Results and discussion

β -lactoglobulin polymorphism

Genotypes and alleles frequencies are summarised in Table 2. We detected six genotypes at the β -Lactoglobulin locus named as AA, AB, AE, BB, BE and EE (Figure 2, Table 2).

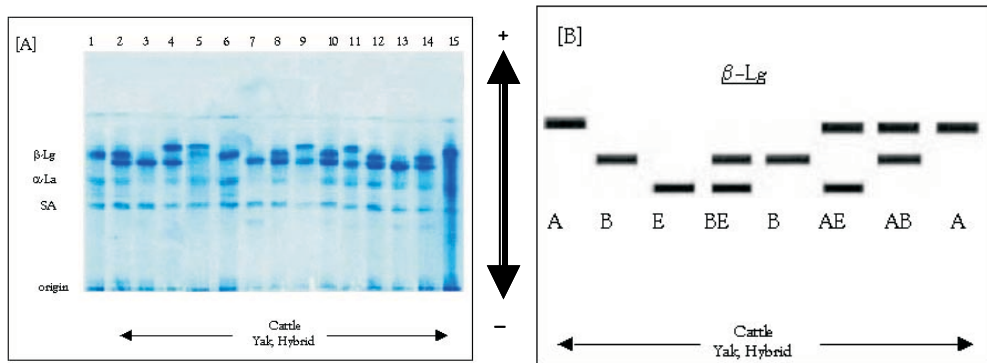
The Tianzhu White yak population was monomorphic showing only the EE pattern. Polymorphisms were found in the other yak populations, in cattle and the F_1 hybrids with the eventual presence at the A, B and E alleles. Allele E was not detected in cattle. It is worth mentioning that alleles A and B, which were previously only observed in *B. taurus* cattle (Kawamoto et al. 1996), are detected exclusively in the heterozygous forms (AE and BE) in yak and their F_1 hybrids. Similarly, allele E, which was proved to occur only in yak

(Grosclaude 1976a; Bell et al. 1981a, b) and Bali cattle (Bell et al. 1981a, b), is also only occurring in heterozygote forms (AE and BE) in F₁ hybrids.

Table 2. Genotypes and alleles frequencies of β -Lg variations in yak, cattle and their F₁ hybrids.

	MQ	LQ	XH	TZW	TZB	SN	F ₁	CH	QC
Locus	No. = 181	No. = 221	No. = 41	No. = 16	No. = 89	No. = 8	No. = 39	No. = 13	No. = 10
Genotypes β -Lg									
AA	0	0	0	0	0	0	0	1	1
AB	0	0	0	0	0	0	0	8	6
AE	0	3	1	0	0	0	9	0	0
BB	0	0	0	0	0	0	0	4	3
BE	2	61	14	0	3	2	30	0	0
EE	179	157	26	16	86	6	0	0	0
Alleles									
β -Lg ^A	0	0.0068	0.0122	0	0	0	0.1154	0.3846	0.4000
β -Lg ^B	0.0055	0.1357	0.1829	0	0.0169	0.1250	0.3846	0.6154	0.6000
β -Lg ^E	0.9945	0.8575	0.8049	1.0	0.9831	0.8750	0.5000	0	0

Note: MQ = Maqu; LQ = Luqu; XH = Xiahe; TZW = Tianzhu White; TZB = Tianzhu Black; SN = Sunan yak.



Note: (A) Simultaneous detection of α -Lactalbumin (α -La) and β -Lg by thin layer polyacrylamide gel electrophoresis (PAGE) (Erhardt 1993). All samples are of the genotype BB for α -La locus. Lanes 1, 6: β -Lg BB, Lanes 2, 8, 10, 12, 14: β -Lg BE, Lanes 3, 7, 13: β -Lg EE, Lanes 4, 9, 11: β -Lg AE, Lane 5: β -Lg AB, Lane 15: β -Lg AA. (B) Diagram showing the β -Lg variants as detected in (A).

Figure 2. The electrophoretic pattern of milk proteins around the β -Lactoglobulin (β -Lg) locus.

The frequency of allele E (not including Tianzhu White yak where it is fixed) is the highest in Maqu yak (0.9945) followed by Sunan yak (0.9831), and the lowest in Xiahe yak (0.8049). The frequency of allele B is the highest in Xiahe yak (0.1829) followed by Luqu yak

(0.1357) and the lowest is in Maqu yak (0.0055). Allele A is only present in two populations of yak, Luqu (0.0068) and Xiahe yak (0.0122). The frequency of allele E in F_1 hybrids is 0.5; it suggests that the parental yak population was fixed for this allele (Table 2). Similar results were obtained in F_1 hybrids by (Grosclaude et al. 1976a, Zhang et al. 1991).

Genetic variation within yak populations and genetic differentiation between yak populations

Genetic variation within yak populations were estimated by Nei's genetic diversity coefficients (Nei 1987) using three milk protein loci of α -Lactalbumin (α -La), β -Lactoglobulin (β -Lg) and β -Casein (β -Cn) (Table 3).

Table 3. Genetic diversity (H_s , H_t) of three milk protein loci.

Locus	MQ	LQ	XH	TZW	TZB	SN	Mean ³	Pooled ⁴
	No. = 180	No. = 220	No. = 41-44	No. = 16	No. = 89	No. = 8-9		
α -La ¹	0	0	0	0	0	0	0	0
β -Lg	0.0110	0.2463	0.3186	0	0.0331	0.2188	0.1380	0.1432
β -Cn ²	0	0.0357	0	0	0	0	0.0060	0.0139
Mean	0.0037	0.0940	0.1062	0	0.0110	0.0729	0.0480	0.0524

1, 2: data according to Qi (2000); 3: H_s , 4: H_t .

MQ = Maqu; LQ = Luqu; XH = Xiahe; TZW = Tianzhu White; TZB = Tianzhu Black; SN = Sunan yak

No genetic variations are found in Tianzhu White yak, whereas, in another two neighbouring populations (Figure 1, A and C), Tianzhu Black yak ($H_e = 1.1\%$) and Sunan yak ($H_e = 7.29\%$) the expected heterozygosity is low. For the Maqu, Luqu and Xiahe yak populations, which originated on Gannan highland pastures and with bordering geographic areas (Figure 1, B), genetic variations were detected in all populations ranging from 0.37% (Maqu yak) to 10.62% (Xiahe yak). Although genetic variations exist within yak populations, the average gene diversity within ($H_s = 4.8\%$) and between populations ($D_{ST} = 0.44\%$) is very small, and so is the genetic diversity grouping all yak population studied in a single one ($H_t = 5.2\%$). The average gene differentiation among yak populations (G_{ST}) of 8.4% indicates that population differentiation is low at these three milk protein loci.

Possible explanations for difference in allele frequencies between population

It is generally accepted that domestic yak were descended from wild yak (*B. mutus*) caught and tamed by ancient Qiang people (a collective name for all ancient nomads in western China) in the Qiangtang and other areas of northern Tibet, and subsequently distributed to the current areas where yak are found (Zhang 1989; Cai and Wiener 1995). Out of the 18 China yak breeds, 10 are widely recognised (Zheng 1985). Although these different yak breeds, for the most part, are living in different areas, they are sometimes sharing grazing

habitats. The natural grazing and transhumance practices make genetic exchange between populations feasible. So, considering its likely single origin and the grazing systems followed by the nomads, all yak populations or breeds might have relatively uniform genetic backgrounds. It is the case for the Nepalese yak (Grosclaude et al. 1976a, Grosclaude et al. 1976b; Kawamoto et al. 1992), the Mongolian yak (Grosclaude et al. 1982) and most of Chinese yak populations (Qi 2000) at the level of milk protein loci. Also, it has been observed that yak populations are sharing the same allele at blood protein and enzyme loci (Men et al. 1989; Namikawa et al. 1992; Tu 1996).

B. taurus cattle breeds have been introduced to yak-raising areas in order to produce hybrids (Zhang 1989; Cai 1990). In areas with better communication systems (e.g. Luqu County) as well as in agropastoral areas (e.g. Xiahe County), such breeding practices are easier to implement. As a result, yak in these areas are more often crossbred with local cattle and exotic western cattle breeds resulting in a change of their genetic background. Although such changes are probably minor, it would explain the presence of some low frequency alleles of cattle origins likely in these populations.

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Milk protein genetic polymorphisms: A comparison between Maiwa yak and Jiulong yak

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Summary

Milk protein polymorphisms were studied by polyacrylamide gel electrophoresis (PAGE) in 100 Jiulong yak and 109 Maiwa yak. Genetic polymorphisms at the α_{s1} -casein, κ -casein and β -lactoglobulin proteins were found in the two breeds but no polymorphism was identified at the α -lactalbumin or κ -casein proteins. Four variants of the α_{s1} -casein (B, C, D and E) protein were detected in both breeds and two variants were identified for the κ -casein and β -lactoglobulin proteins. Significant differences in allelic frequencies at the α_{s1} -casein and κ -casein proteins were found between the Maiwa and the Jiulong yak breeds.

Keywords: Milk, protein polymorphism, yak

Introduction

Milk protein polymorphisms have received considerable research interests in recent years because of the significance of some genetic variants in cheese making properties of milk and their relationships to milk, fat and protein yields (Lin et al. 1992). Although most researches on milk proteins were related to major components (such as the α_{s1} -casein and β -casein), MUC1, a minor protein component of milk, has also received a lot of interest due to its potential practical values (Patton 1999). Milk protein polymorphism and the quantitative differences in the expressions of some alleles have been studied by gene analysis as well as by PAGE methods (Medrano and Aguilar-Cordova 1990; Lum et al. 1997). DNA variants within the 5'-flanking region of milk-protein-encoding genes have also been reported (Bleck et al. 1996). However, relatively limited information to date is available on yak milk protein polymorphisms (Zhang et al. 1991; Zheng and Han 1996). The purpose of this study was to determine the genetic variants of milk proteins in Jiulong yak and Maiwa yak.

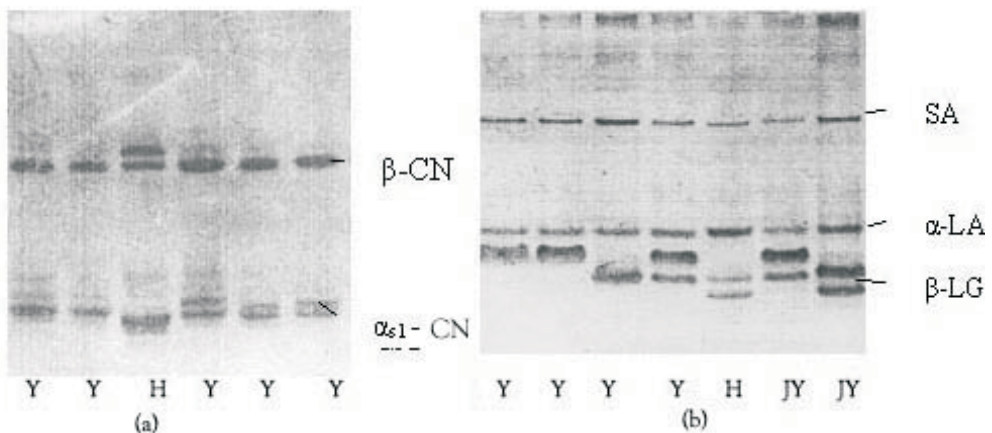
Materials and methods

This study involved two breeds: 100 Jiulong yak from Jiulong County and 109 Maiwa yak from Hongyuan County. Following hand milking in the morning, small (approximately 30 mL) quantities of milk were collected from individual yak cow. A few milk samples of Jiulong yellow cattle and Chinese Holstein cows were also collected as controls. These samples were frozen (-20°C) and transferred to laboratory for analysis.

Milk protein typing was performed on 15×15 cm PAGE using the procedure of Medrano and Sharrow (1989).

Results and discussion

The electrophoretic distributions of the main casein fractions are showed in Figure 1a. Only the A variant of the β -casein (β -CN) was identified in Jiulong and Maiwa yak. Larger loading volumes were needed for the detection of the κ -casein alleles (data not shown). The electrophoretic pattern of whey proteins is showed in Figure 1b. All the samples were homozygous for the BB allele of the α -lactalbumin (α -LA). Quantitative differences in the expression of β -lactoglobulin (β -LG) alleles were observed. Heterozygotic yak are producing more β -LG B than of β -LG A as indicated by the intensity of the two stained bands. It confirms previous finding (Zheng and Han 1996) and could be the result of transcriptional or post-transcriptional regulation of the β -LG gene (Lum et al. 1997).



Y = yak, H = Chinese Holstein, JY = Jiulong Yellow cattle, α_{s1} -CN = α_{s1} -casein, β -CN = β -casein, SA = serum albumin, α -LA = α -lactalbumin, β -LG = β -lactoglobulin. From left to right, the genotypes of α_{s1} -casein are DD, DD, BB, CE, BD, CE; the genotypes of β -LG are DD, DD, BB, BD, AB, BD, AB.

Figure 1. Polyacrylamide gel electrophoresis (PAGE) patterns of casein (a) and whey proteins (b).

Milk protein genotypes and allelic frequencies at the Jiulong and Maiwa yak are indicated in Table 1. α_{s1} -casein DD genotype was the most common genotype in Maiwa yak. DD, DE genotypes were observed at similar frequencies in Jiulong yak. Two variants were identified for the κ -casein and β -LG loci. The genotypic distributions of the α_{s1} -casein and κ -casein proteins variants were significantly different between Jiulong and Maiwa yak ($P < 0.01$) and did not follow Hardy-Weinberg equilibrium within the two breeds (χ^2 -test, $P < 0.01$). Similarly, the genotypic distribution of the β -LG variants was not in agreement with Hardy-Weinberg equilibrium in Jiulong yak ($P < 0.05$).

Table 1. Genotypic frequencies of milk proteins in Maiwa and Jiulong yak.

	α_{s1} -casein								κ -casein			β -lactoglobulin		
	BD	BE	CC	CD	CE	DD	DE	EE	AA	AB	BB	BB	BD	DD
Maiwa	0.009	0.018	0.10	0.050	0.046	0.780	0.046	0.050	0.030	0.147	0.853	0.010	0.046	0.954
Jiulong	0.030		10.060		0.070	0.380	0.360			0.340	0.630		0.040	0.950

The most common allele for the α_{s1} -casein locus is allele D, for the κ -casein locus it is allele B and for the β -lactoglobulin locus it is allele D (Table 2). In most breeds of cattle α_{s1} -casein B and β -LG B are the commonest alleles. Also, the κ -casein A allele is the commonest in Holsteins and Ayrshires cattle, whereas in the Jerseys it is the κ -casein B allele (Lin et al. 1992; Medrano and Sharrow 1989). The different variants and genotype frequencies observed in this study at the α_{s1} -casein and β -LG loci between yak and cattle breeds illustrate the difference in milk composition observed between the two species. The allelic frequencies observed at the β -LG locus in Maiwa and Jiulong yak is different from the ones reported by Zhang et al. (1991) in Qinghai yak.

Table 2. Allelic frequencies at milk protein loci in the Maiwa and Jiulong yak.

	α_{s1} -casein				κ -casein		β -lactoglobulin	
	B	C	D	E	A	B	B	D
Maiwa	0.014	0.124	0.807	0.055	0.073	0.927	0.023	0.977
Jiulong	0.015	0.120	0.600	0.265	0.200	0.800	0.030	0.970

Although milk protein typing directly by PAGE is simple and cheap, poor resolution of some protein variants could be a problem. Genetic typing of bovine milk protein loci following DNA PCR amplification has been developed in recent years (Medrano et al. 1990; Lum et al. 1997). The accurate and early identification of milk protein genotypes at the DNA level in both females and sires is allowing to establish breeding programs aiming to increase the frequency of the desired milk protein alleles in dairy cattle population. A similar approach will be useful in yak.

Acknowledgments

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Population genetic variations of haemoglobin in yak, cattle and their hybrids

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Summary

Polyacrylamide gel electrophoresis was used to analyse haemoglobin (Hb) polymorphism in six yak populations (Jianza County of Qinghai Province, Sunan County, Tianzhu County, Maqu County, Luqu County and Xiahe County of Gansu Province), two cattle populations (Wuwei City and Linxia County of Gansu Province) and one F₁ hybrid population (Linxia County). The results show that the Hb locus in yak consists of only one genotype (Hb^{AA}). At the opposite the Yellow cattle studied show three alleles (Hb^A, Hb^B and Hb^C), with three genotypes detected in the population from Linxia County (Hb^{AA}, Hb^{BB}, Hb^{BC}) and five genotypes detected in the population from Wuwei City (Hb^{AA}, Hb^{AB}, Hb^{BB}, Hb^{BC} and Hb^{AC}). The F₁ hybrid population has three alleles (Hb^A, Hb^B and Hb^C) with three genotypes (Hb^{AA}, Hb^{AB} and Hb^{AC}). In cattle and in cattle × yak hybrid the commonest allele is Hb^A.

Keywords: Cattle, haemoglobin, hybrid, polymorphism, yak

Introduction

As a unique domestic animal living in the high altitude zones, the yak (*Bos grunniens*) remain productive in the extreme environmental condition of the Qinghai–Tibetan Plateau where hardly any other livestock can survive. China is a main country on yak husbandry and it has more than 95% of the total yak population in the world.

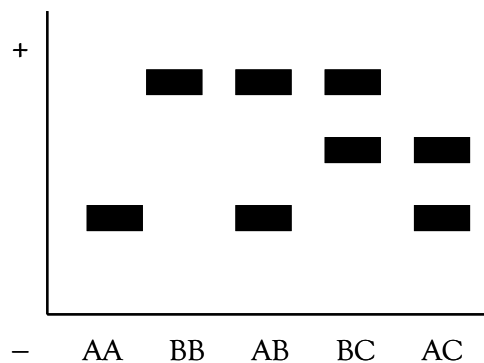
Haemoglobin (Hb) is the major carrier of oxygen in the blood. Genetic variation at the protein might reflect adaptation to local environmental conditions. Ranchev (1981) and Nyamsamba and Zagdsuren (1994) identified three genotypes (Hb^{AA}, Hb^{AB} and Hb^{BB}) and two alleles (Hb^A and Hb^B) in Mongolian yak. However, no polymorphisms were identified in Tianzhu White yak, Nepalese yak, Jiulong yak, Tibetan yak and Maiwa yak (Men et al. 1989; Qi et al. 1991; Namikawa et al. 1992; Cheng et al. 1995; Zhong et al. 1999).

The purpose of this study is to extend these previous findings into a larger geographic area with the analysis of new yak populations. Also, we will compare genetic variation in yak' haemoglobin with the ones present in Yellow cattle and hybrids Yellow cattle × yak.

Materials and methods

Samples of six yak populations were collected from Sunan County ($n = 38$), Tianzhu County ($n = 63$), Maqu County ($n = 69$), Xiahe County ($n = 20$), Luqu County of Gansu Province ($n = 36$), and Jianza County of Qinghai Province ($n = 43$). Two cattle populations, from Wuwei city ($n = 46$) and Linxia County of Gansu ($n = 22$), and one F_1 hybrid population from Linxia ($n = 45$) were also analysed.

Gel electrophoresis conditions were in accordance to the findings of Han et al. (1996). After electrophoresis the gel was dyed using Commassie Brilliant Blue (G250) for about thirty minutes and then washed in 7% acetic acid solution. We used the standard nomenclature from Namikawa et al. (1992) for the calling of the Hb genotypes (Figure 1).



Source: Namikawa et al. (1992).

Figure 1. Possible haemoglobin genotypes.

Results and discussion

In this study, we could not identify polymorphism at the Hb locus in 269 yak samples from six populations. Only the HbAA genotype was found in yak. At the opposite the two Yellow cattle populations were polymorphic at the Hb loci. We identified three alleles and four genotypes in the Linxia population, meanwhile the same alleles and five genotypes were present in the Wuwei population. The Hb loci of F_1 hybrid population were also polymorphic with three alleles and three genotypes (Table 1). The allele and genotype frequencies in F_1 (Yellow cattle \times yak) is similar to the ones found by Namikawa et al. (1992) in the Nepalese hybrids of yak \times cattle.

The absence of polymorphism at the haemoglobin locus in yak populations analysed in this study and previous works which failed to identify any polymorphism in all but one population of yak (Ranchev 1981; Men et al. 1989; Qi et al. 1991; Namikawa et al. 1992; Nyamsamba and Zagdsuren 1994; Cheng et al. 1995; Zhong et al. 1999) strongly support that genetically pure yak populations will be monomorphic at the haemoglobin locus for allele Hb^A. Also, it suggests that the HbAA genotype might have been selected in yak given

its possible stronger affinity for oxygen. Therefore, Hb polymorphism present in Mongolian yak (Ranchev 1981; Nyamsamba and Zagdsuren 1994) show past hybridisation efforts in yak population.

Table 1. Allelic and genotypic frequencies observed at the haemoglobin locus.

Population	No. of animal	Allele frequencies			Genotype frequencies				
		A	B	C	AA	BB	AB	BC	AC
Wuwei cattle	46	0.794	0.163	0.043	0.717	0.087	0.110	0.043	0.043
Linxia cattle	22	0.909	0.068	0.023	0.910	0.045		0.045	
F ₁ hybrids	45	0.967	0.022	0.011	0.934		0.044		0.022
Yak	269	1.000			1.000				

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Genetic variants at the H subunit of the lactate dehydrogenase protein in milk of Maiwa and Jiulong yak

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Summary

The isozymes of the lactate dehydrogenase (LDH) in the skim milk of 109 Maiwa and 100 Jiulong yak were assayed by polyacrylamide gel electrophoresis (PAGE). Usually one band (LDH₁) was observed for each sample. However, four genetic variants of LDH₁ were detected and named A, B, C and D according to their electrophoretic mobilities. The D variant was only observed in the Jiulong yak. The C variant was the commonest within the two breeds. There was a significant difference in frequencies of LDH₁ phenotypes between the Maiwa and the Jiulong yak.

Keywords: Isozyme, lactate dehydrogenase, milk, yak

Introduction

Lactate dehydrogenase (LDH) is an oxidoreductase involved in glycolysis in tissues of animals. LDH usually exhibits five types of isozymes (LDH₁ to LDH₅). Amano et al. (1990) reported the presence of phenotypes of LDH₁ in red cells of Tibetan yak. Two genetic variants of LDH₁ were also identified in red cells of Qinghai yak and in plasma of Maiwa yak (Zhang et al. 1994; Zhong et al. 1998). Zheng and Chen (1997) reported three genetic variants (A, B and C) of LDH₁ in serum of the Tibetan yak. Moreover, the LDH isozyme patterns of serum between yak with A or B variants and yak with C variant are also different (Zheng and Chen 1997). In view of the involvement of LDH in glycolysis under anaerobic conditions and the hypoxic habitat of yak, genetic variants of LDH₁ might have physiological significances.

The purpose of this study was to analyse the LDH isozymes in milk of Maiwa yak and Jiulong yak to get a better understanding of biochemical properties and genetic variation of LDH in yak.

Materials and methods

One hundred and nine Maiwa yak, 15 hybrids of male Tibetan Yellow cattle × female Maiwa yak (Hongyuan County), 100 Jiulong yak, 15 Jiulong Yellow cattle, and 8 hybrids of Jiulong Yellow cattle × Jiulong yak were sampled by collecting approximately 30 ml of morning milk from each individual cow. These samples were frozen and then transferred to laboratory for analysis. The phenotypes of LDH isozymes in the skim milk were assayed after gel electrophoresis on a 6.5% PAGE as reported by Zheng and Chen (1997).

Results and discussion

LDH isozymes pattern in the milk of yak, Yellow cattle, and their hybrids show the LDH₁ band (Figure 1), in agreement with our previous results on the Maiwa yak (Zheng and Han 1997). LDH is widely distributed in tissues and fluid of human and animals. The main source of LDH in milk is white cells and epithelial cells of mammary gland. The relative activity of LDH₁ is $93.50 \pm 2.45\%$ in normal bovine milk, $70.90 \pm 0.82\%$ in mammary gland tissue, and $56.40 \pm 6.21\%$ in white cells (Wang and Zou 1995). LDH₂–LDH₅ isozymes were not noticed even after long period of staining of the gels.



1 to 10 represented 10 milk samples of Jiulong yak. The phenotypes of LDH₁ were: 3-B, 4-A and 6-D; others are C. 6.5% PAGE gel, 10 μ l skim milk were loaded per well.

Figure 1. Electrophoresis of LDH isozymes in yak milk.

LDH₁ shows polymorphism in yak and its hybrids. It includes A, B, C and D phenotypes, named according to their mobilities from fast to slow after gels electrophoresis (Figure 1). The phenotypic frequencies are listed in Table 1. A, B and C phenotypes of LDH₁ were found in both Maiwa and Jiulong yak. LDH₁-C was predominant in both breeds. Only very slight difference of mobility existed between LDH₁-A and LDH₁-B variants. In four milk samples of Jiulong yak, a band (classified temporarily as D) with slower mobility than the C phenotype was observed. It is close to the mobility expected for LDH₂ or

LDH₃ bands. However, we think it is a new genetic variant of LDH₁ in regards to its relative high enzymatic activity similar to that the ones observed at other variants of LDH₁.

Table 1. Phenotypes of LDH₁ in milk of yak, Yellow cattle and their hybrids.

Breeds	Number	A	B	C	D
Maiwa yak	109	0.0092	0.1284	0.8624	
Jiulong yak	100	0.0700	0.3100	0.5300	0.040
Maiwa hybrid	11		0.0910	0.9090	0
Jiulong Yellow cattle	15			1.000	
Jiulong hybrid	8			1.000	

There was a significant difference in distribution of the phenotypic frequencies of LDH₁ variants between Maiwa yak and Jiulong yak (Table 1, $P < 0.05$). Also, a special LDH isozyme pattern with a frequency of 5% was detected in the milk of Jiulong yak (data not shown). It consists of two to five narrow bands with the first band migrating approximately to the same distance than the LDH₁-A or the LDH₁-B band. Also, the second and the third band of this pattern have the highest enzymatic activities as indicated by their stronger intensities. Whether these bands are identical or related to any of the LDH₁ to LDH₅ bands previously identified is unknown. In a separate study, we had identified 3 to 4 LDH isozyme bands in the colostrums of Maiwa yak with the LDH₁ bands being the one showing the highest enzymatic activity (Zheng and Han 1997).

Our findings regarding genetic polymorphisms at LDH₁ are identical with that of Zhang et al. (1994) and Zhong et al. (1998), who have identified in Maiwa yak, Amano et al. (1990), who have identified in Tibetan yak, Zhang et al. (1994) and Zhong et al. (1998), who have identified in Qinghai yak. LDH₁-C phenotype frequency of Jiulong yak (53%) is significantly lower than in Maiwa yak (approximately 68.9% to 86.7%). Differences in frequencies of LDH₁ variants between Maiwa and Jiulong yak support their classification in two distinct breeds. Such distinction is also supported by blood protein polymorphism data (Tu et al. 1997).

Acknowledgments

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Cloning and sequencing of 5'-flanking region of kappa-casein gene in yak

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Summary

Primers designed using sequence of kappa-casein gene in cattle (*Bos taurus*) are adopted to amplify the corresponding 5'-flanking sequence in yak (*Bos grunniens*). The amplified DNA fragment of 436 base pairs (bp) are cloned and sequenced. Comparisons of the sequences among cattle, sheep (*Ovis aries*), goat (*Capra hircus*) and human (*Homo sapiens*) identify a possible recognition site for transcription factor 'NF-AT^{h, m}' within the yak and cattle sequences (length 16 bp, position -329 to -334 nucleotides in yak), which does not exist in the sequences of sheep and goat. A 20 bp fragment (from the position -83 to -102 nucleotides in the yak sequence) is found in the sequences of yak, cattle, sheep and goat but it is not present in the corresponding region within the human sequence. The function of this fragment remains unknown.

Keywords: Gene, kappa-casein, regulation factor, yak

Introduction

Expression and regulation of casein genes is one of the most studied models in biochemical and genetic researches. It is well known that kappa-casein plays an essential role in the formation, stabilisation and aggregation of milk micelles, but several questions linked to the regulation and expression of this gene are still unanswered. Schild et al. (1994) reported 15 DNA variants located within the promoter region (+115/-1073) among 13 cows from seven breeds. But mutations associated with the difference of milk production characters among different breeds were not identified. Coll et al. (1995) reported the structural features of the 5'-flanking region of goat kappa-casein gene. All these previous studies show that recognition sequences of transcription factors present in other milk protein genes could be found in the promoter region of the kappa-casein gene. However, they are all in the distal region part of the promoters (>400 bp). In the proximal promoter region only two transcription factor (AP2 and AP1) recognition sequences have been reported (Schild et al. 1994). Yak, cattle, sheep, goat and human have very distinguished milk-producing ability, so it is expected that comparison of the sequences among these species would help to

understand their functions. This paper reports, for the first time, the 5'-flanking sequence of yak kappa-casein gene.

Materials and methods

Two primers, amplifying the fragment from -397 nt to +41 nt in the cattle kappa-casein gene including the partial sequences of intron 1 and the 5'-flanking region, were designed and used to amplify the corresponding region of 436 bp in yak (F1: 5'ATTACTTCATACTCAGGTTCTT3', F2: 5'GCTTGGCAGTAGGTTTCAGTTGG 3') (Alexander et al. 1988).

PCR conditions: The PCR reaction mix was made of 2.5 μ L buffer (500 mM KCl, 100 mM Tris-HCl, 15 mM MgCl₂, 0.01% gelatin), 2 μ L dNTPs (2.5 mmol/ μ l), 0.5 μ L of primers F1 and F2 each (50 pmol/ μ L), 1 U *Taq* DNA polymerase, 100 ng of template DNA extracted from muscle tissue samples, and then ddH₂O up to 25 μ L. The temperature cycling was as follows: 5 min (95°C), then 30 cycles for 1 min (95°C), 1 min (61°C) and 2 min 30s (72°C), incubation at 72°C for 10 min, then storing at 4°C.

The PCR products were cloned into the PCRTM II T-vector and the recombinant plasmids transformed into the *E. coli* XL₁-Blue strain. DNA for sequencing was prepared by the alkaline lysis method (Sambrook et al. 1989). ABI PRISM™ 377 DNA Sequencer was used for sequencing.

Results and discussion

Figure 1 shows the structure of the proximal 5'-flanking region of the yak kappa-casein gene where no recognition sequence of the mammary gland specific transcription factor is found. However, there are several recognition sequences of non-mammary specific transcription factors such as AP-2, TCF-1, CF1, NF-IL6, PEA3, GATA-3, OTF-2, ATF, which are all hormone responding factors (Faisst and Meyer 1992). So, it is supposed that the proximal region of the kappa-casein gene plays an essential role for the expression and regulation of the gene. In addition, the typical TAAT-box and CAAT-box are identified in position -25 nucleotide (nt) and -75 nt, respectively, with the former not present both in sheep and goat.

This partial sequence of yak with its counterpart of cattle, goat, sheep and human are compared (Figure 2) and the results show that there is a 16 bp insertion in the cattle and yak sequences, from -329 nt to -334 nt, but not present in the sheep and goat sequences. Comparison of this fragment with the recognition sequences of other regulation factors shows 80% homology with the transcription factor NF-AT^{h, m}. Therefore, we assume that the fragment may contain a potential recognition site for NF-AT^{h, m}. It is known that the function of the NF-AT^{h, m} is regulated by the cyclosporin A and FK506 and that NF-AT^{h, m} is involved in the immuno-suppressive response of cyclosporin A (Faisst and Meyer 1992). However, the function of this specific fragment remains unknown.

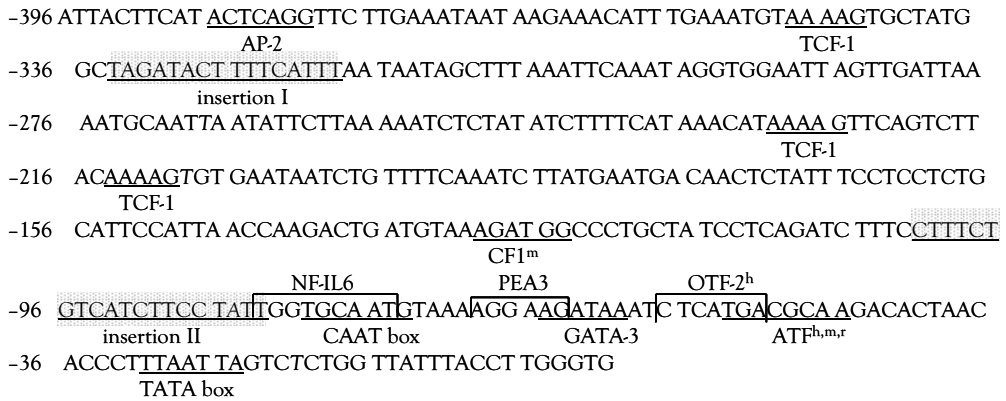


Figure 1. Structure of proximal 5'-flanking region of the yak kappa-casein gene.

There are 14 sites of mutations between *Bovidae* species (yak and cattle) and *Caprinae* species (goat and sheep) in the region sequenced (Figure 2). It is clear that some of these mutations play an essential role in the difference in milk production characters between the *Bovidae* and *Caprinae*, although not all of these mutations appear to affect the expression of the gene. For example, the -75 deletion leads to the loss of the CAAT box in sheep and goat sequences and the -226 deletion leads to the loss of a TCF-1 factor recognition site. In this case, these two mutations would influence the expression of the gene.

In this region of the gene, we also identify a long inserted fragment in yak (-65 to -374 nt) and a repeat sequence (-102 nt to -210 nt) related to the LIPA2 repeat sequence family in human. The function of this fragment is unknown.

Fragment from -83 nt to -102 nt in yak does not exist in the corresponding region of human sequence but it is present in cattle, sheep and goat. BLAST search in the GenBank database indicates that the fragment is present in the genome of a lot of species but at different locations. Possibly it may be a very important regulation factor recognition site. However, further analyses regarding its possible function in yak, cattle, sheep and goat are needed.

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Yak5GAAAATG TAAAAGTGCATGGCTAGATACTTTTCATTTAATAATAGCTTTAA	51
Cattle (a)	51
Cattle (b)	.....	51
Goat	.....c.....t	35
Sheep	.....t	35
Human	aagccttatgatgtagactctacatcc-tctctgcatt-c-ttt-tat-tta-t-t-tt-tt-att	75
↓		
Yak5	ATTCAAATAGGTGGAAATTAGTTGATTAAAAATGCAATTAATATTCTTAAAAAT. CTCTATATCTTTTCATAAAACAT	125
Cattle (a)	.....c	126
Cattle (b)	.....c	126
Goat	.....a.....a.....g.....c	110
Sheep	.....a.....a.....g.....cc	110
Human	t-att.....t-t-c-tt-g-tt-egg-ac-tgtgcaca-tgtg-agg-t-gtt	135
↓		
Yak5	AAAAGTTCAGTCTTACAAAAGTGTGAATAA..... TCTGTTTTCAAATCTTATGAATGACAACCTCTA	187
Cattle (a)	.....	188
Cattle (b)	.....	188
Goat	.....a.....a.....g.....	172
Sheep	.....a.....a.....g.....	172
Human	-tgt-a-a-tgtgccatgct-gtgc-c-gcacccactaactcg-atc-ag-ttagg-atc-cc-tg-	210
↓		
Yak5	TT.. TCTCTCTGCATTCCATTAACCAAGACTGTAGTAAAGATGGCCCTGCTATCTCAGATCTTTCCTCTG	260
Cattle (a)	.....g.....g	261
Cattle (b)	.....g.....g	261
Goat	.....t-t.....tg.....g	245
Sheep	.....t-t.....tg.....g	245
Human	-ccc-c-actcc-ccc-a-ccc-c-ac-ccc-g-a-a-tc-ta-g.....	278
↓		
Yak5	TCATCTTCCTATGGTGCAATG TAAAAGGAAGATA. AATCTCATGACGCAAGACACTAACACCCTTTAATTAGTC	334
Cattle (a)	.....	335
Cattle (b)	.....	335
Goat	.....g.....c.....	319
Sheep	.....g.....c.....	319
Human	.....aa-a-gg-g-a-g-ag-g-t-gt-t-g-	340
↓		
Yak5	TCTGGTTATTACCTGGGTGTCCTTA. CAGTGG	368
Cattle (a)	.....a.....	370
Cattle (b)	.....a.....	369
Goat	c.....t	353
Sheep	c.....tc	353
Human	-tca-tt-c-tc-ct-	374

Note: '-' indicate that the base is the same as in the reference sequence (yak). The 'letters' in lower case indicate the position and nature of a point mutation sequence between the other species and the yak. '.' indicates the position of a deletion.

Sources: Yak (this study, GenBank accession number AF194988); cattle (a) (Alexander et al. 1988, GeneBank accession number X14906); cattle (b) (Groenen et al. 1993, GeneBank accession number M75887); sheep (Spira et al. 1994, GeneBank accession number L31372); goat (Coll et al. 1995, GeneBank accession number Z33882); human (Edlund et al. 1996, GeneBank accession number U51899).

Figure 2. Sequences comparisons of the proximal kappa-casein 5'-flanking region between yak, cattle, sheep, goat and human.

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Opportunities for the improvement of yak production with particular reference to genetic options

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Summary

Opportunities for the improvement of yak production are discussed. The non-genetic routes to improvement include nutritional inputs—limited by the availability of supplementary feeds—changes in range management, disease control and increased marketing opportunities. Genetic routes to improvement, examined in more details, include selection, crossbreeding and hybridisation. Some of the opportunities and difficulties inherent in each are referred to. Consideration is also given to the potential use of genetic markers, locations on chromosomes identified by molecular techniques. These could be an aid to selection if found to be favourably associated with performance traits or disease resistance in the yak. However, in addition to investment in the molecular procedures, such associations have to be established through recording of performance and parentage identification on a large scale. These prerequisites are therefore the same as for conventional breeding schemes for yak. In the medium term, such conventional schemes are likely to be less expensive and more certain to be effective, in achieving the desired results, than reliance on molecular techniques. We concluded that until the molecular technology has advanced much further, to see what it can realistically offer to the improvement in yak productivity, it is important to support long-established practices to safeguard a future for domestic yak and for a way of life that it underpins.

Keywords: Crossbreeding, genetic markers, genetics, improvement opportunities, selection, yak

Introduction

The title of this paper reflects the fact that we want to stress the importance of improvement in yak production—in those situations where it can be applied for the benefit of the herdsmen. There are several ways of achieving such improvement, which will be referred to. However, much of the paper will deal with genetic options for change.

A substantial improvement in productivity from yak is of great importance to provide a significant increase in the income and standard of living of yak herders and their families.

Without any improvements, it seems likely that over the next 20 years or so there will be a significant decline in the yak population and a major shift in human population away from these highland regions. This is only a prediction, and the trends are not yet very obvious in China. But the basis for believing that such a decline may happen, if not prevented, is already apparent in some of the smaller countries with severely declining yak populations such as Nepal and India, to name but two. Movement of people away from remote rural areas is also seen everywhere in the world as a result of people wanting to improve their standard of living and have available some of the modern facilities offered in towns and cities—in spite of the risk that the aspirations of such a move may not be realised. Improvement in income from yak production would be one important component in restoring some balance and in helping to maintain a way of life and keep the yak as a unique genetic resource.

The opportunities for improvement of yak production are constrained by the environment and by access and importantly by social, cultural and economic considerations. Some of the main components of change, where these are applicable, will now be discussed.

Review and discussion

Non-genetic routes to improvement

Nutritional inputs: Major changes are limited by distance from areas where crop by-products are available and by the limited opportunities for growing supplementary feed *in situ*, even with the possible advent of genetically adapted crops, although systems for such production are under investigation (Liu 1999). There is clearly a potential for providing supplementary feed in the form of feed blocks for emergency use especially during harsh winters to prevent death of animals (Zhang 1998; Long et al. 1999). However, this does little to improve output except in terms of reducing immediate losses. Strategic feeding in late winter or early spring and over the calving period can reduce losses among adult animals and assist both the survival and growth of calves through the better condition and milk output of their dams. The costs and benefits of such strategic supplementations will need to be evaluated against the costs of doing nothing.

Range management: Long and Ma (1996) discussed an increasing degradation of rangelands used by yak, and the consequent threat to yak nutrition and survival, along with measures needed to reverse this situation. There are good opportunities for improvements in animal productivity by techniques to improve range management, including a reduction in overgrazing, when that is its cause, which would also help to reduce parasite burdens. Early disposal of surplus stock and of castrate males at much younger ages than is commonly practised would reduce pressure, particularly on winter pastures. Although the castrates so disposed of, if not needed as pack animals, may be smaller and perhaps fetch a lower price (provided they can be marketed), the benefit in terms of extra feed made available for the more productive females should improve the overall output from the herd. In the longer term, progressive changes in plant varieties and the introduction of legumes may improve

pasture output. However, taking account of the large areas involved, these improvements will take a long time to achieve in full.

There have also been some relatively recent changes, made or proposed, which involve fencing of individual holdings and affect the access to land by yak herders. There may be good reasons for these changes, but it has yet to be shown whether they are neutral in their effect on good range management or actually harmful. Richard (2000) discussed both positive and negative consequences of such subdivisions of grazing and rangelands.

Disease prevention: There are real opportunities for prevention and cure of a number of parasitic and infectious diseases and other causes of ill health in yak. The limiting factors appear to be access to professional help and the costs in relation to the benefits.

Marketing: The provision of additional outlets for the major yak products and the development of more niche markets for specialist yak products is a route to increase income—but this depends on finance and political will to initiate such schemes. Substantial benefits could come from a concerted marketing effort of yak products with a high add-on value. An example from Nepal is the systematic introduction of cheese factories for the use of yak milk since 1952 (Thapa 1996; Joshi et al. 1999).

Genetic routes to improvement

Genetic improvement, once achieved, is permanent and does not involve recurrent costs except in terms of maintaining the more productive animals. Several different breeding schemes could be developed to provide significant improvements in productivity. The opportunities are largely within the direct control of the herders themselves and represent a challenge to them, but also require assistance from the scientific communities and government departments. In particular, the investigations needed to identify and develop the best breeding practices need scientific and technical inputs and support from public funds. The importance of this cannot be overstressed.

We will now review, briefly, the genetic options for change, some of which have been discussed at previous yak congresses. Included in our consideration are the possible new opportunities from advances in molecular techniques.

Variation: Without genetic variation in the yak population there can be no genetic change. Both the maintenance and exploitation of genetic diversity is therefore important. Genetic variation is found in the putative existence of different yak breeds, although the extent and nature of these differences is not yet well established, and in variability within breeds.

Breed differences can be exploited by substituting, over a period of years, one breed for a more productive breed (if a real difference in performance has been accurately established). However, direct importation of a new breed is unlikely to be practical or cost-effective if the different breeds are isolated from each other by large distances. Crossbreeding is a simpler way of introducing the characteristics of one breed into another. Initially, crossbreeding may also bring additional benefits from hybrid vigour, but this will be progressively lost as the existing breed is 'graded-up' to the new breed. In a wider context, breed substitution should not be extended to the point of losing genetic diversity in the yak population. Crossbreeding among yak breeds and the creation of new 'synthetic' breeds, however, need

not lead to loss in genetic variation. (A point to be borne in mind is that the first cross of two breeds may, as already referred to, show heterosis. The extra performance due to this should not be attributed to the 'better' parent breed and then lead automatically to breed substitution. Clear differentiation between additive and non-additive genetic effects is a prerequisite of effective crossbreeding strategies).

As a start, it is important that the nature and extent of breed differences and the effects of crossbreeding should be clearly shown through proper investigation. Also, any role which genotype–environment interactions may play in affecting the performance of different breed and crossbred types needs to be established. Wiener (1996) and Wiener (1997) discussed these points. The exploitation of breed differences through crossbreeding, and the concomitant reduction in risks from inbreeding within herds, have been argued previously as a practical and immediate route to the genetic improvement of yak productivity.

The use of semen from wild yak is a special case of such crossbreeding and requires no separate consideration. To provide a valid comparison, however, the crossbred and the purebred animals have to be managed and treated in the same way and in the same place. Otherwise, it is impossible to apportion any improvement to heterosis on the one hand or additive genetic effects on the other, or to distinguish genetic from the non-genetic effects on performance. The possibility that crosses of domestic yak with wild yak may be given better conditions than the ordinary yak makes it difficult to provide a genetic interpretation of some of the results to date.

Hybridisation: The crossing of yak with *Bos taurus* cattle is well established, particularly at the lower elevations and where better feed may be available. It is apparent that the hybrid females produce more milk and are superior in growth and in other respects to pure yak. However, it is far from clear to what extent this is due to heterosis or to additive genetic effects and what role genotype–environment interactions play in the results. The main reason for this is that of the three types—the cattle, the yak and the hybrids—the pure cattle are generally not present as females in the same environment as the yak. This is particularly the case when these cattle are exotic breeds like the Holstein—the types from which most of the benefits of hybridisation are claimed. A secondary reason is that, in all probability, the hybrids get better treatment than the purebreds. A further problem with the use of hybrids, as a means of increasing herd output, derives from the sterility of the hybrid males. This limits the breeding systems that can be employed. Moreover, because of the relatively low reproductive rate of the yak in traditional production systems, only a limited proportion of yak can be used for hybridisation if the pure yak population is to be maintained. Thus, the overall economics of hybridisation is not simple to establish and is unlikely to be as beneficial as the better milk yield or growth rate of a hybrid animal might imply. Wu (2000) discussed some of these matters

Conventional selection: In the medium- or long-term, selection of superior genotypes is the principal way to improve the genetic potential for animal productivity. For the yak, the major constraint, at present, is the lack of recorded information on pedigrees and on the performance of the animals—performance in terms of reproduction, milk production and milk composition, growth rate and meat characteristics, specialist fibre production for niche markets, disease resistance, and so on. The colour of animals, the size and shape of

horns and similar traits are often admired by herders but are of very doubtful value. Such traits are entirely counter-productive to schemes for the improvement of productivity. Cai and Wiener (1995) and Wu (2000) described a traditional scheme.

The establishment of effective selection schemes for the improvement of yak productivity is complicated and detailed consideration cannot be given here. Wiener (1994a) outlined the principles and Wiener (1994b) and Wiener (1994c) gave greater details. It seems likely, however, that the application most likely to succeed in yak would be through the establishment of some form of group breeding scheme and concentrating attention on a very restricted number of the economically most valuable traits—perhaps only one or two.

Such schemes depend on the willingness of a number of yak herders to agree on their objectives for improvement and to pool their animal resources for selection purposes. Superior females and males are identified over the whole of the yak population and it is these alone, which are allowed to breed the bulls, which are then used over the whole group. The superior females derived from all the participating herds need not be kept together in a single nucleus herd, but in the case of yak this may be the best option, as the necessary recording of pedigrees and performance can then be largely restricted to the nucleus group. The use of artificial insemination (AI), to distribute semen from the best bulls, is something that might be appropriate in some areas, but is not an essential component of such schemes. For the most part, the use of AI faces formidable difficulties in yak rearing areas. Further advances, given the technological inputs—which are not, as yet, successfully developed in yak—could come from the use of multiple ovulation and embryo transfer (MOET) using the very best females as donors of embryos and as the dams of the future bulls. Such technology can be incorporated into formal MOET schemes (Nicholas 1996), but, worldwide, the application of this methodology has not been as great as the theoretical advantages might have suggested. The control of excessive inbreeding, resulting from the use of a relatively small number of parents of future generations, has been a major constraint even where the technology itself is established. Similarly, other new techniques which may be broadly regarded as increasing female reproductive rate such as *in vitro* maturation of oocytes and cloning have, at best, very limited potential as solutions for practical breeding problems and are potentially associated with serious disadvantages in terms of reducing genetic diversity (Nicholas 1996; Woolliams and Wilmot 1999).

We will now consider briefly whether new molecular techniques may assist in the process of selection by better identifying superior genotypes.

Marker-assisted selection: The most important tool used in genome research is the genetic marker. Currently, the most useful genetic marker is the microsatellite marker. These markers may simply be thought of as signposts along animals' chromosomes, i.e. they mark known locations on the chromosomes. An important feature of these markers is that they are very variable, i.e. have many alleles. In other words, a known marker at a known location on a chromosome will vary between animals, and even within animals: the copy or allele received from an animal's dam may differ from the copy received from the sire. Currently, many hundreds of markers are known for each major domestic species (pig, cattle, sheep and goat) and a lesser number, to date, for yak.

1. **Parentage testing:** The simplest use of genetic microsatellite markers is for parentage testing. To assign the correct parent to an animal from a number of potential parents, it is necessary to characterise the animal for a number of markers (e.g. 6–10), and characterise the potential parents for the same markers. By the rules of heredity, an animal must inherit the marker from its parent. Therefore, the parent will be the only animal, which, for each marker, has an allele in common with the progeny animal.
2. **Enhancing genetic progress:** Markers can be used to detect chromosomal regions likely to contain one or more genes affecting performance. If important regions containing beneficial genes have been found, it is possible to demonstrate which versions of the markers are consistently associated with desirable performance characteristics. Typically, this must be done in large populations to avoid obtaining associations with markers that are due to chance, rather than a true genetic relationship. These regions are known as Quantitative Trait Loci (QTL). Selection, which uses these marker associations, is known as marker-assisted selection.

Marker-assisted selection is currently being performed in dairy cattle, where markers for milk yield have been identified in commercial populations (breed) (Arranz et al. 1998; Coppieters et al 1998) and in pigs, where markers have been identified for litter size. Marker-assisted selection is most beneficial for traits that are difficult or expensive to measure, traits that only occur in one sex (e.g. milk or reproduction) or traits that are expressed late in life (e.g. longevity). A potentially and particularly beneficial use of markers is for selection for disease resistance (Crawford et al. 2000). If a genetic marker is available that indicates resistance to a particular disease, it would be possible to reduce or even eliminate the disease without having to expose the animals to the disease.

Another potential use of genetic markers is for importing a desirable copy of a gene from one population or breed (A) to another population or breed (B). In this case, populations A and B are crossed and the crossbred offspring are bred back to population B. Markers are used to ensure that all the animals used for breeding have the desirable gene. This process is known as introgression.

3. **Genetic diversity:** A further use of genetic markers is for quantifying genetic diversity. The more similar different breeds are, the more similar will their markers be. Conversely, breeds, which are genetically more different, will show greater differences between their markers. Markers are especially important when considering genetic conservation programmes. Steane (1997) has discussed the importance of maintaining genetic diversity in yak and some of the strategies for this.

In general: The molecular technology is being developed in the yak. DNA analysis, mostly of microsatellite origin, is in progress with yak both in China and Bhutan, and in the UK (Han Jianlin, personal communication, 2000). It must be re-emphasised, however, that variation at the molecular level does not, on its own, provide information about differences in animal performance or disease resistance, between or within breeds, or on the likely effects of crossbreeding or inbreeding. There is a possibility that genetic markers, found to be associated with particular aspects of performance or disease resistance in other Bovidae, or in other species of animals, may also be found to be similarly associated in the yak. However, having regard to some major differences between yak and other species, there is

no safe alternative to establishing the actual correlations, if any, between markers and performance traits in the yak. As referred to earlier, these investigations would have to be done with large populations to avoid the risk of chance associations—and such work would be demanding, time-consuming and costly. Moreover, conventional selection programmes could be expected to be effective on their own, without the adjunct of genetic markers, if the prerequisite of parentage and performance recording was widely practised, and if AI and embryo transfer techniques could be made widely available across the yak population, instead of being localised as at present.

We should also add that because different yak populations differ in a number of respects readily seen by eye, such as differences in colour, which are almost certainly genetic in origin, it is not surprising, that some differences in DNA profiles are evident from microsatellite studies. Thus, it is all the more important to establish whether variation in DNA profiles is also related to genetic variation in animal performance and health. Microsatellite and DNA profile information may be used to choose between breeds for crossbreeding or breed substitution. If two populations are very similar in their DNA profiles, it is probable that these would not be good first candidates for crossbreeding trials or for breed substitution. This is the converse of saying that populations, which differ substantially in these profiles, are especially useful as candidates in schemes for conservation of genetic diversity.

Inbreeding: As argued in earlier papers (Wiener 1994a; Cai and Wiener 1995; Wiener 1996; Wiener 1997) there is a distinct risk of inbreeding in yak. This arises because, within herds, a small number of males are often used for several years—possibly only one dominate male having most of the progeny. He is then likely to be followed by a son or other close relative. Recent evidence based on investigations using microsatellite markers suggests that a high level of heterozygosity (around 60%) may be present in the yak population studied (Dorji 2000) and that inbreeding may not therefore be the concern once thought. However, it is a feature of inbreeding that the process moves genetic variation from within families (e.g. herd) to between families. It is possible therefore that the inference of inbreeding from traditional breeding practices, within herds, can be reconciled with the maintenance of genetic diversity at the population level.

Some inbreeding is, in the long-term, also a consequence of selection or, as in the case of yak now in the USA and Canada, from having a small base population from which the expansion in numbers has occurred. Inbreeding causes a deterioration of reproductive performance, growth, survival and general vigour. Inbreeding should, therefore, be avoided as far as possible. There are useful reports of yak breeders' groups where active measures are now taken to avoid this long-standing and risky strategy of close breeding. In this situation, molecular information could have a role in avoiding mating together of animals that are particularly alike in their DNA profiles. This, however, is only the theory. It is unlikely, nor cost-effective, to provide the necessary infrastructure for such DNA profiles, or the scale of animal identification that would be required. Conventional procedures for identifying individual animals leading to the development and use of pedigrees would seem a more immediate strategy for controlled breeding practices than the use of DNA profiles without pedigree information. Moreover, the pragmatic approach to the practical reduction of

inbreeding is to rotate bulls among a number of herds, so that no bull is ever likely to be mated to his own daughters or other close female relatives.

Closing remarks

Setting aside the social, cultural and economic constraints applicable to any improvement programme, there are opportunities for the improvement of yak production by both genetic and non-genetic routes. It is important to try to achieve such improvements to enhance the income of the herders and to secure a future for yak production. Most genetic improvements in yak are likely to come, within the immediately foreseeable future, from traditional animal breeding methods. However, the contribution that molecular genetics may be able to make has also to be considered.

Molecular genetics is both modern and exciting, in so far as it lays bare the underlying pattern of heredity. It is attractive to researchers and relatively successful in attracting funding. Until the time, however, when far more genes are identified and far more is known about the association of particular genes with particular aspects of animal performance, the molecular approach will not add significantly to what the traditional geneticist, animal breeder and herder could achieve now in the yak. Immediate benefits from using genetic markers are more likely in the pursuit of maintaining genetic diversity and assisting conservation programmes, and, where necessary, in parentage verification.

In conclusion, the yak industry would be badly served if the attractions of molecular genetics, as an academic pursuit in the search for knowledge and some of its potential uses, were to detract from the overriding need to provide funding for mundane but essential breed comparisons, crossbreeding trials and selection schemes in relation to genetic improvement, and for the non-genetic routes to improvement.

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Session III: Nutrition and feeds

Advances in yak nutrition research

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Summary

The yak nutrition research group at the Qinghai Academy of Animal and Veterinary Sciences has been studying yak digestion metabolism, energy metabolism, nitrogen metabolism and nitrogen supplementary techniques since 1985. The research includes the following aspects: 1) Rumen digestion metabolism, in terms of parameters such as pH, TCA-P, $\text{NH}_3\text{-N}$ and TVFA, was tested in 1- to 3-year-old yak with permanent rumen fistula and raised under different conditions. The results show that each parameter is affected by the different conditions under which the yak are raised. The higher the nutrition level, the higher the main parameters but the lower the pH value. 2) Fasting energy metabolism was tested in 1 to 3 year old yak with closed circuit respiratory masks and feeding at different altitudes. The results indicate that the fasting heat production (FHP) of the yak was stable at the altitudes of 2300–4300 metres above sea level (masl). The zone of thermo neutrality was 8–15°C, and, at relatively lower altitudes (e.g. 2300 masl), the $\text{FHP} = 302.13 \text{ kJ/kgW}^{0.75}$, $\text{ME}_m = 458 \text{ kJ/kg W}^{0.75}$ and $\text{Km} = 0.66$, which are similar to that in cattle at similar altitudes but different at higher altitudes. 3) Intake, digestion and utilisation of protein in grasses during different phenological periods by growing yak were systematically studied under natural grazing conditions. 4) Protein requirement for maintenance and growth were estimated and the utilisation of non-protein N in yak was investigated. 5) Nutrient fluctuation in grasses on the alpine frigid meadow was systematically surveyed. From the point of views mentioned above, the protein balance between different phenological periods and between animal and pasture are discussed. Concerning protein shortage during the cold season, some nitrogen direct supplement methods are suggested. It was found that to maintain a proper ratio of energy and protein, molasses–urea block could be given to yak for 200 days during the cold season. Using this method, the digestible protein of yak can be increased by 35%, which basically meets the level for maintaining the energy–protein balance and reduces body weight loss remarkably. During the warm season, indirect nitrogen supplementation using nitrogen fertiliser can also have a beneficial effect.

Keywords: Energy, metabolism, nitrogen, rumen, supplementary techniques, yak

Introduction

There are about 13 million yak in China, which account for about 90% of the world's total yak population. Yak, a unique livestock species domesticated on the Qinghai-Tibetan Plateau, is

the dominant livestock on the Plateau because of its ability to adapt to anoxic environment and grass shortages at higher altitudes over 2500 masl. Yak provide raw material for local herders' production activities. However, research on yak, especially on nutrition, remains far behind that on other livestock due to natural and social constraints, which have resulted in both blind production strategies and inefficient research programmes, such as that related to yak breeding for example (Cai and Wiener 1995). It is well known that nutrition research is very important to plan feeds and feeding. The yak nutrition research group at the Qinghai Academy of Animal and Veterinary Sciences has been studying systematically digestion metabolism, energy metabolism, nitrogen metabolism and nitrogen supplementary techniques related to yak nutrition since 1985, with significant results.

Rumen digestible metabolism

Rumen digestible metabolism of growing yak under different feeding conditions

Rumen parameters of 1- to 3-year-old castrated and fistulated yak were compared under conditions of barn, grassland and meadow pasture. It was found that these parameters do not vary among age groups, but the total volatile fatty acid (TVFA), trichloro acetic acid-protein (TCA-P), ammonial nitrogen ($\text{NH}_3\text{-N}$) and number of ciliate protozoa do vary depending on pastureland conditions, such as barn, grassland and meadow pastureland (Bi et al. 1989; Xie et al. 1989; Liu et al. 1992). The better the nutrition condition, the greater the parameter values but the smaller the pH value (Tables 1 and 2).

Table 1. Nutrition levels under different feeding conditions.

Items	Grassland		Meadow		Barn
	Green (September)	Yellow (October)	Withered (December)	Green (August)	
Grass production (kg/hectare)	1506.2	713.1	282	474.8	-
Gross energy (GE) (kJ/g)	17.6 ± 0.5	17.0 ± 0.7	18.4 ± 0.8	17.8 ± 0.6	17.2
Crude protein (CP) (%)	13.5 ± 1.4	7.6 ± 1.3	7.4 ± 0.7	12.4 ± 1.5	13.6
Acid detergent fibre (ADF) (%)	35.5 ± 2.2	43.7 ± 1.8	46.7 ± 1.9	31.8 ± 1.9	45.4

Table 2. Items of rumen fluid under different feeding conditions.

Items	Grassland		Meadow	
	Green	Withered	Green	Barn
Dry matter (%)	1.88b	1.70b	1.83b	-
pH	6.79bc	6.87ab	6.93a	6.77c
TVFA ($\times 10^{-2}$ mol/L)	4.57a	2.15b	3.90a	2.70b
$\text{NH}_3\text{-N}$ ($\times 10^{-2}$ mol/L)	16.48a	3.88c	7.68b	8.26b
TCA-P (g/L)	3.17b	9.62a	2.79b	7.10a
Ciliate number ($\times 10^8$)	4.31a	2.22b	3.25b	6.13a

It is worth mentioning that the pH, TVFA and NH₃-N in yak fluctuated twice during the daytime when yak were fed twice a day, but did not change so much on the lower productive pasture.

Comparison of TVFA under different feeding conditions

The concentrations of acetic acid, propionic acid and butyric acid were tested under green grass, yellow grass, withered grass and barn feeding conditions (Liu et al. 1992; Xie et al. 1992). The results follow the general law that the absolute amount and value of high-efficient acid is higher under better nutrition conditions, which is also true for water buffalo and yellow cattle. However, the results show that the ratio of high-efficient acids in yak is much higher than for other ruminants (Tables 3 and 4).

Table 3. Rumen total volatile fatty acid (TVFA) under different grazing conditions (1×10^{-2} mol/L).

Items	Grazing conditions			Barn		
	Green grass	Yellow grass	Withered grass	Maintenance	Regular	High level
TVFA	5.4 ± 0.5	1.8 ± 0.3	0.6 ± 0.2	3.2 ± 0.7	3.4 ± 0.3	4.1 ± 0.5
Acetic acid	2.5 ± 0.2	a little	a little	1.6 ± 0.4	1.5 ± 0.1	1.8 ± 0.2
Propionic acid	1.4 ± 0.2	1.2 ± 0.2	0.2	0.8 ± 0.2	1.0 ± 0.1	1.2 ± 0.2
Butyric acid	1.4 ± 0.3	a little	a little	0.8 ± 0.2	0.7 ± 0.1	1.0 ± 0.1
Acetic acid (%)	46.3	-	-	45.8	44	42.8
Propionic acid (%)	26.2	-	-	22.7	29.7	28.4
Butyric acid (%)	25.8	-	-	24.2	20.8	23.3
C ₂ /C ₃	1.8 ± 0.1	-	-	2.0 ± 0.3	1.48	1.5

Table 4. Compositional changes in total volatile fatty acid (TVFA) among ruminants (%).

Animal	High concentrate and low rough feeds		
	A	B	C
Cattle	6-75	15-21	5-14
Sheep	65-71	15-24	8-15
Deer	54-70	15-24	10-17
Buffalo	54.7	27.44	16.7
Yak	43.6-44.3	29-31	20.6-21.3

Rumen fluid volume and speed in growing yak

Taking polyethylene glycol (PEG) as fluid dilution, the volume and moving speed of rumen fluid were observed to be 33.8 L and 3.26 L/h (CV<5%) from 4 (150 kg BW) castrated

fistulated yak (Liu et al. 1991). This was equivalent to 67%, which is 48% of that found in yellow cattle.

Protein degradability of feedstuff in yak

Degradability of 11 feedstuffs was determined using a nylon bag method fitted to the rumen fistulae (Xue and Han 1998). The result shows that the protein digestibility of garden pea, highland barley, formaldehyde fish meal, skimmed dry acidification milk, corn, garden pea straw, meat and bone meal are higher in yak rumen, but lower for fish meal, wheat bran, rapeseed meal and formaldehyde rapeseed meal (Table 5).

Table 5. Protein degradability of feedstuff in yak rumen.

Feedstuff	Crude protein	Dry matter
Corn	0.68	0.68
Garden pea straw	0.56	0.30
Rapeseed meal	0.44	0.49
Garden pea	0.85	0.73
Fish meal	0.49	0.50
Skimmed dry acidification milk	0.79	0.74
Meat and bone meal	0.55	0.54
Highland barley	0.83	0.82
Formaldehyde fish meal	0.81	0.59
Formaldehyde rapeseed meal	0.38	0.32
Wheat bran	0.48	0.49

Energy metabolism

Fasting heat production (FHP) of growing yak at different altitudes

Under natural temperature in summer, the FHP of growing yak does not differ ($P > 0.05$) between the altitudes of 2261 masl, 3250 masl and 4272 masl; but does vary ($P < 0.05$) among age groups (Table 6). Table 6 shows that the FHP of yellow cattle increases significantly ($P < 0.05$) with the increase of altitude. This is an important difference between yellow cattle and yak (Hu et al. 1992). The relationship between body weight and FHP is expressed by the equation $FHP = 920W^{0.52}$ kJ/day ($n = 25$, $r = 0.8469$; $P < 0.01$).

To test the accuracy of the exponential value (0.52) in the equation above, a paper-sticking method was used to measure the surface area of growing yak (Hu et al. 1989). The result indicates that the surface area is highly correlated with the 0.52th power of body weight.

Table 6. Fasting heat production (FHP) of growing yak and yellow cattle under natural temperatures.

Altitude (masl)	Age (year)	Number of animals		Heat production (kJ/kgW ^{0.75} ·d)	
		Yak	Yellow cattle	Yak	Yellow cattle
2261	1	3	3	351.544 ± 25.744	292.395 ± 7.563
	2	7	4	305.344 ± 20.920	250.516 ± 3.610
	3	6	4	302.185 ± 17.911	219.061 ± 2.313
3250	1	3	4	328.873 ± 6.249	414.430 ± 7.456
	2	4	4	321.363 ± 6.160	53.260 ± 2.457
	3	4	4	327.737 ± 7.745	357.357 ± 3.164
4271	1	3	2	376.252 ± 23.518	516.372
	2	3	2	324.787 ± 46.044	387.925
	3	3	2	281.144 ± 24.410	359.940

Effect of ambient temperature on FHP

Statistical analyses correlating FHP with environmental temperatures indicate that the FHP is slightly correlated with ambient temperatures ranging between 23°C and -30°C, remains similar between 8°C-15°C, and increases when the temperature is higher than 15°C. FHP exhibits a downward trend when temperatures decrease, and increases again sharply when temperatures drop lower than -20°C. Other physiological attributes such as respiratory rate, heart rate and body temperature remain the same between 8°C and 15°C (Table 7), which indicates that 8°C-15°C is the zone of thermo neutrality for yak (Han et al. 1992a).

Table 7. Regression equation between temperature and fasting heat production (FHP).

Temperature range	Y = a + bX	n	r	Significance
-30°C - -20°C	FHP = 891 - 18.4T	37	-0.2917	P<0.05
-20°C - 0°C	FHP = 1188 + 15.5T	40	0.4744	P<0.01
0°C - 10°C	FHP = 1155 + 13.8T	46	0.2431	P<0.05
8°C - 15°C	FHP = 1080 + 0.7T	52	0.0066	P>0.05
15°C - 23°C	FHP = 1070 + 10.5T	48	0.2735	P<0.05

Energy conversion efficiency of growing yak

In barn with different feed levels, 30 energy-balance trials were conducted on six yak aged 2 to 3 years to determine FHP (Han et al. 1997). When dietary concentrate increased from 50-90%, general energy increased from 14.393 MJ to 75.092 MJ, energy digestibility from 60-77%, the metabolic rate from 50-70%, and the precipitation rate from 9-25%. On the other hand, faecal energy loss was reduced from 40-23%, urine energy loss was reduced by half, and heat production remained stable around 46% (above the maintenance level) (Table 8).

Table 8. Energy metabolism of yak under different feed levels.

Group	BW (kg)	GE (MJ)	FE (MJ)	UE (MJ)	CH ₄ E (MJ)	HP (MJ)	DE/ GE (×10 ²)	UE/ GE (×10 ²)	CH ₄ E /GE (×10 ²)	ME/ GE (×10 ²)	HP/ GE (×10 ²)	RE/ GE (×10 ²)	AD WG (kg)
1	86-93	14.39	5.74	0.24	1.27	11.57	60	1.7	6.80	49	80	-31	-0.26
	128-151	20.82	7.50	0.46	1.83	15.57	64	2.2	8.80	53	75	-22	-0.47
2	86-94	23.46	7.44	0.47	1.74	11.76	68	2.0	7.40	59	50	9	0.16
	120-143	34.68	10.15	0.89	2.60	15.85	71	2.6	7.50	61	46	15	0.20
3	87-96	30.06	8.69	0.58	2.11	13.91	71	1.9	7.00	62	46	16	0.19
	124-156	46.53	14.11	1.10	3.40	20.67	71	2.3	7.00	62	43	19	0.57
4	93-103	36.65	11.51	0.69	2.53	16.98	69	1.9	6.90	60	46	14	0.39
	133-166	62.38	15.52	1.11	1.12	25.54	75	1.8	6.60	67	41	26	0.71
5	99-109	43.01	9.99	0.44	2.84	21.82	77	1.0	6.60	69	51	18	0.35
	145-177	75.02	16.99	0.83	4.20	35.36	77	1.1	5.60	71	47	24	0.65

BW= body weight; GE= gross energy; FE= faecal energy; UE= urine energy; CH₄E= methane energy; HP= heat production; DE= digestible energy; ME= metabolic energy; RE= retention energy; ADWG= average daily body gain.

Using a regression analysis of ME/kgW^{0.75} and RE/kgW^{0.75}, MEm = 458 kJ/(kgW^{0.75}·day), metabolic energy efficiency for maintenance Km = 0.66 and energy efficiency for fattening K_f = 0.49 have been obtained. The metabolic energy demand for growth has been measured by means of a factorial method ME (MJ/day) = 1.393 W^{0.52} + (8.732 + 0.091W) ΔG (Han et al. 1997). A forty-day trial was conducted, in which 72:28 (concentrate:rough) feed was given to castrated yak with a body weight of 100–200 kg, in order to test the theoretical value.

The metabolic rate (MR) was estimated once again using a method which compared rough type diet feed (concentrate:rough 28:72) and typical diet feed (concentrate:rough 48:52). No significant difference (P>0.05) was found between MR rough = 0.470 and MR typical = 0.478, though the metabolic rate exhibited a downward trend when the concentrate was converted to coarse (Han et al. 1992b). More studies are needed to decide whether the results are characteristic of yak or due to an inaccurate calculation formula.

Effect of the amount of motion on energy metabolism

Two-year-old yak (BW about 120 kg) were compared with yellow cattle when they walked on pasture at an altitude of 3000 masl and at the speed of 1 m/second (s) and 1.5 m/s. It was found that heat production in motion is significantly more (P<0.01) than that when standing (Han et al. 1989) and heat production in motion at 1.5 m/s is significantly more (P<0.01) than that at 1 m/s. Furthermore, yak produce significantly more heat in motion (P<0.01) than do yellow cattle (Table 9).

Table 9. Comparison of heat production in motion at different speeds between yak and yellow cattle (kJ/kgW^{0.75}/minute).

Species	Number	Standing	Motion at V ₁	Motion at V ₂
Yak	4	0.345 ± 0.003	1.924 ± 0.047	2.347 ± 0.107
Yellow cattle	4	0.314 ± 0.031	1.479 ± 0.125	1.748 ± 0.106

These observations fit with the law that small animals produce more heat. They also imply that, in spite of its adaptation to local conditions, yak consume a large amount of energy, and thus a scientific grazing pattern appears to be very necessary to reduce the heat loss.

Nitrogen metabolism

The protein requirement of growing yak

Twenty-seven yak, 1–1.5 years old, were fed different rations in two trials to determine N metabolism (Xue et al. 1994). In trial 1, nine yak were given a low N ration with 0.985% to study the degradation of endogenous N and the lowest maintenance N. In trial 2, 18 yak were divided into three groups and then fed rations with 6.7, 10.1 and 13.4% CP, respectively. The purpose was to study protein requirements for maintenance and growth, and to evaluate the effect of dietary protein levels on N metabolism. The results are shown in Table 10.

Based on trials 1 and 2, the following four formulae were developed:

1. Digestible CP requirement for minimum maintenance = $2.012W^{0.52}$ (g/day).
2. Digestible CP requirement for maintenance (DCPR_m): DCPR_m = $6.61W^{0.52}$ (g/day), obtained with low N ration, or DCPR_m = $6.09W^{0.52}$ (g/day), obtained with N balance trial.
3. Digestible CP requirement for growth (DCPR_g) = $(0.0011548/\Delta W + W^{0.52})^{-1}$ (g/day).
4. Total digestible CP requirement = $6.09W^{0.52} + (0.0011548/\Delta W + 0.0509/W^{0.52})^{-1}$ (g/day)

Table 10. Effect of dietary protein levels in feed rations on body weight gain, carcass weight and N digestibility.

Protein level	6.7%	10.1%	13.4%
N intake (g/day)	19.0 ^A	32.0 ^B	41.8 ^c
N retention (g/day)	4.0 ^A	7.3 ^B	11.7 ^c
N deposit rate (%)	21.1 ^a	22.8 ^a	28.0 ^b
Apparent N digestibility (%)	51.8 ^A	65.9 ^B	73.8 ^c
True N digestibility (%)	72.4 ^{Aa}	78.4 ^b	83.5 ^{Bc}
BW gain (kg/day)	0.054 ^{Aa}	0.194 ^b	0.247 ^{Bc}
Carcass weight (kg)	77.5 ^a	81.1 ^{ab}	90.5 ^b
BW gain/feed consumed	0.025 ^a	0.091 ^b	0.116 ^b

Uppercase letters (i.e. A, B and C) indicate very significant differences (P<0.01). Lowercase letters (i.e. a, b and c) indicate significant differences (P<0.05).

Apparent digestibility of grass N

Digestibility of grass under different phenological conditions is shown in Table 11 (Liu et al. 1996). It is easy to see that as grass turns yellow and dry, the CP digestibility goes down.

Table 11. Digestibility of grass crude protein (CP) during different phenological periods (g/head per day).

Item	Sprout	Green	Yellow	Dry
	May-June	July-September	October-November	December-April
Animal number	6	7	6	6
Intake	436.48	318.70	283.65	161.32
Excretion	147.61	128.19	120.08	110.28
Digested	288.87	190.51	163.57	51.04
Apparent digestibility (%)	66.18	59.78	57.67	31.64
DM digestibility (%)	74.34	66.58	62.10	38.45

Biomass and nutrient content in alpine frigid meadow pasture

Alpine frigid meadow is the main pasture category in the Qinghai highland and accounts for 49% of all edible pastures there. To study the nutrient dynamics of the pastures, an investigation in different seasons was conducted, the results of which are presented in Table 12 (Xie et al. 1996a).

The biomass of pasture is highest in August and then goes down month by month, until the lowest value is obtained in May. CP values in June are the highest, and then drop down to 8.4% in October. The content of coarse fibres is just the opposite. There is a strong negative correlation ($r = -0.895$) between the contents of CP and coarse fibre. Ca and P contents are the same as CP. The gross energy of grass generally does not change so much between seasons (Xie et al. 1996a).

Table 12. Aboveground biomass and nutrient contents in grass in different months.

Item	Year (1992)						Year (1993)	
	June	July	August	September	October	November	April	May
Biomass (g/m ²)	21.91	74.27	96.82	64.6	58.8	57.0	48.91	22.25
GE (MJ/g)	1.66	1.77	1.80	1.78	1.78	1.72	1.64	1.87
CP (%)	15.38	12.19	11.44	10.4	8.44	6.81	2.96	-
Crude fat (%)	3.46	4.64	4.92	4.16	4.30	3.66	1.88	2.46
Coarse fibre (%)	22.34	23.26	26.14	26.9	30.5	29.2	-	-
Crude ash (%)	14.60	11.72	9.00	8.79	10.3	9.58	7.03	13.08
Ca (%)	1.27	1.25	1.03	1.15	0.85	-	0.81	0.95
P (%)	0.15	0.13	0.11	0.11	0.05	0.06	0.07	0.14

Dry matter basal

A heavy loss of biomass and grass nutrients was observed during winter and spring. The portion of biomass lost was 77 and 65% for CP. The loss rate for P, 30%, is the lowest among the nutrients. The grass conservation rate during the cold season was 48.3%, which is only 60% of the theoretical rate (80%). Thus, during the cold season, only with enough nutrient supplements could the normal growth rate of yak and other animals be maintained.

Digestible protein intake of yak during different seasons

From the feed intake (Table 13), nutrient contents in grass (Table 12), and grass protein digestibility in different phenological seasons (Table 11), the digestible protein intake of yak during different periods was calculated (Table 14). This result is important for this study as the following result is mainly formatted according to these data.

Table 13. Feed intake of yak during different phenological periods.

Season	Age (year)	BW (kg)	Intake (kg/head per day)		
			By adjust	By 4N-AIA ¹	Average
Green	2	115.34±2.68	3.98±0.32 ^a	3.86±0.59 ^a	3.92 ^{Ba}
	3	154.42±1.37	6.00±0.82 ^b	5.50±0.49 ^b	5.75
Yellow	2	125.96±2.28	3.79±0.53 ^a	3.65±0.46 ^a	3.72 ^{Ba}
	3	168.09±1.10	5.80±0.45 ^b	5.49±0.81 ^b	5.65
Dry	2	120.11±2.40	5.30±0.90 ^a	5.59±0.95 ^a	5.45 ^{Bb}
Sprout	2	122.60±1.67	6.82±0.53	-	6.82 ^A

1. 4N-AIA: 4N (acid equivalent) acid insoluble ash.

Table 14. Digestible protein intake of yak during different phenological periods.

Item	Green	Yellow	Dry	Sprout
Feed intake (kg/head per day)	3.92	3.72	5.45	6.82
CP% in grass	10.94	7.63	2.96	15.38
Digestibility (%)	60.25	56.36	31.60	69.86
Protein intake (g/head per day)	258.38	159.97	50.98	723.77

Real protein intake and potential requirement of growing yak

From formulae 2 and 4, the digestible protein requirement for maintenance and growth (100 g and 500 g BW gain/day) was calculated (Table 15). During the green season, the protein in grass is sufficient to meet the maintenance requirement of yak, and for them to gain 300–400 g BW daily. During the budding season, the protein in grass is enough to allow a 500 g BW gain/day. During the dry season, however, digestible protein in grass is not enough to maintain body weight (only 55% of the requirement is met), so that yak BW gain is negative during this period, a result that sounds reasonable. It is clear that N supplement is needed to support yak growth and/or maintain body weight during the cold season.

Rumen peptide absorption of growing yak

The result showed that dietary protein is mainly absorbed in the form of peptide in growing yak and the non-mesenteric system is the main site of peptide absorption (Han et al. 2000). Peptide and amino acid absorption levels are related to the intake of digestible crude protein

and have no relation to total crude protein. The higher the intake of digestible crude protein, the higher the absorption of peptide but the lower the absorption of amino acids.

Table 15. Protein intake and requirement of growing yak during different phenological seasons.

Item	Green	Yellow	Dry	Budding
	July–September	October–November	December–April	May–June
BW (kg)	115.34	125.96	120.11	122.60
Biomass (g/m ²)	80.69	57.92	43.55	49.18
CP intake (g/head per day)	258.38	159.97	50.98	732.77
Requirement for maintenance (g/head per day)	89.94	94.16	91.86	92.85
100 g BW gain	78.82	79.79	79.27	79.50
200 g BW gain	123.96	126.38	125.08	125.64
300 g BW gain	153.20	156.91	154.91	155.78
400 g BW gain	173.68	178.47	175.88	176.99
500 g BW gain	188.83	194.50	191.43	192.75

Nitrogen supplementary techniques

Supplementary molasses–urea block for grazing yak during cold seasons

The blocks contained 40% molasses, 10% urea, 13.5% rape seed cake, 10% wheat bran, 13.5% grass mill, 2% salt, 1% trace elements and 10% binder elements. Samples were left at certain pasture sites for 199 days, and on average 110 g were consumed by each yak per day (Table 16). The blocks were proved very efficient for yak between 2 and 3 years old but not for yak 4 years of age (Xie et al. 1995; Chai et al. 1996).

Table 16. Bodyweight (BW) gain in molasses–urea licks (199 day trial) BW (kg/head).

Age	Group	Number	BW at the beginning	BW by the end	BW loss	Significance
2	Control	7	88.37 ± 12.53	65.56 ± 6.06	22.81	P<0.05
	Test	7	85.18 ± 8.79	78.23 ± 11.20	6.89	
3	Control	7	133.16 ± 8.71	107.85 ± 11.78	25.31	P<0.01
	Test	7	136.56 ± 14.69	133.55 ± 10.53	3.01	
4	Control	7	166.35 ± 10.45	145.32 ± 16.13	21.08	P>0.05
	Test	7	159.74 ± 17.66	138.84 ± 20.13	20.90	

Trial using complex urea licks during cold seasons

These blocks contained 30% urea, 28% salt, 30% (NH₄)₂HPO₃, 7% (NH₄)₂SO₄, 3% molasses, 2% trace elements and a little of binder. More than 80 yak were fed for 167 days with an average daily amount of 34 g for each yak. Only in the 3-year-old group was there an

obvious effect ($P < 0.05$). It seems that molasses was necessary for the N supplement (Wang et al. 1997).

Effect of N fertiliser on grass yield and nutrients on alpine frigid meadow

Grass yield and nutrients on alpine frigid meadow increased by 110.2% and 172.27%, respectively, and CP content increased by 126.39% and 196.10%, when N fertiliser was used on alpine frigid meadow at the rate of 50 kg and 80 kg/hectare. From 1 kg of N, 11.8 kg of grass, or 1.35 kg of N in grass, was harvested (in August) (Xie et al. 1996b). However, no influence was found in the other nutritional components, like the total N and N in soil (Table 17).

Table 17. Effect of N fertiliser on the grass yield.

Pasture type	Group	Area (km ²)	Yield (g/m ²)		Increase (%)	Grass (kg)/N(kg)
			Before	After		
Alpine frigid meadow	Control	24.46	30.43	229.60	100	14.68
	Test	14.73	34.94	347.00	151.13	
Mountainous dry steppe	Control	30.00	29.91	98.64	100	9.00
	Test	20.00	28.99	170.62	172.97	
Average	Control	54.46	30.17	164.12	100	11.84
	Test	34.73	31.97	258.81	157.70	

Comprehensive measure to increase N intake under grazing conditions

From the results in Table 15, a model is presented in Figure 1. During the 170 days of the cold season, protein intake was lower than the maintenance requirement, so that 115 g BW was lost every day, or 19.6 kg for a whole year (average value for yak 2–4 years old). In the warm season, the daily BW gain was 200–500 g, totalling 64.5 kg/year. Thus, the net average BW gain/year is about 45 kg, which is reasonable in practice. From this point of view, the N direct supplement measure should be mainly considered during the cold season.

Drawing on the results of the trial about real protein intake, potential requirement and methods for N supplement, a model for the N supplement is presented in Figure 2. Different methods for the N supplement can keep the N intake level at or close to the maintenance requirement during the cold seasons. Supplement methods in the cold seasons can increase the intake level by 35% for yak to meet maintenance requirements. In fact, yak in the test group only lost 15–20 g BW per day during the cold season, and 16 kg in the whole period.

In addition, an indirect N supplement during the warm season, in the form of N fertiliser, can increase grass N yield by about 9%, and grass yield by 57% (Hu 1997). This is equivalent to 923 g digestible protein per Mu (1 hectare = 15 Mu) of pasture (after taking

into account the grass and protein lost during winter and the low digestibility influence during the cold season), and 35 g of digestible protein per day for each yak. Thus, the maintenance requirement can be met.

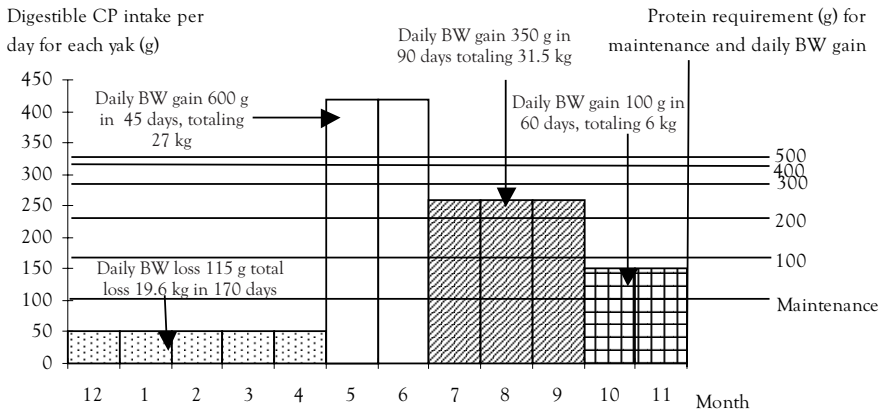


Figure 1. The balance between digestible protein requirement and supplement of grazing yak.

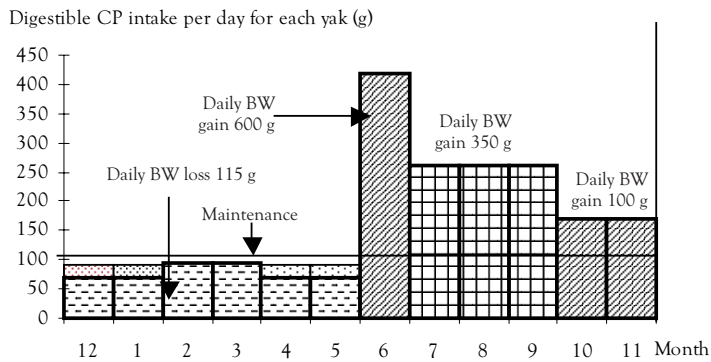


Figure 2. Effect of N supplement on body weight gain.

In summary, the N supplement should be given to animals during the cold season; if possible, during the green season, N fertiliser should be used for winter-spring pasture (50–80 kg of N fertiliser/ha) to increase grass in the same year and next. According to the grass yield and stock rate, animals should be given supplements of molasses-urea blocks and

complex urea blocks, and depending on the herd structure, the ratio of the two kinds of blocks should be 1:1. In the critical period or for fattening, some concentrate pellets should also be given.

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Urea enriched finger millet (*Elensine coracana*) straw: Effect of feeding on yak

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Summary

The experiment was designed to find the suitability of using urea-enriched straw in yak. Three yak were subjected to feeding trial with three rations: millet straw (phase I), 200 g urea/30 kg straw (phase II), and 400 g urea/30 kg straw (phase III). Urea treatment did not increase dry matter intake in yak. Dry matter digestibilities of the three treatments (58.6, 58.6 and 61.2%, respectively) were not different. Crude protein digestibility, digestible crude protein and nitrogen balances were significantly different between the three rations. Digestible crude protein contents of the three diets were 2.09, 5.36 and 8.74%, respectively. The results of biochemical characterisation of strained rumen liquor and serum also revealed differences among animals. The treatment of straw with urea affected total nitrogen and total volatile fatty acids in strained rumen liquor and urea in serum. Ammonia nitrogen in strained rumen liquor and serum glucose remained unaffected.

keywords: Biochemical composition, digestibility, finger millet straw, urea, yak

Introduction

It is well known that simple nitrogenous compounds are broken down in the rumen by the microbial population and utilised to build up microbial protein, which ultimately finds its way into the true stomach, get digested and absorbed in the lumen of the intestine as amino acids (Maynard and Loosle 1951). However, opinions differ on the extent of utilisation of such simple nitrogenous compounds by the host bovid. Urea feeding to animals were attempted on large scale during the second world war because of serious shortage of protein supplements viz. oil cakes.

Urea, a very simple nitrogenous compound (Co: $\text{NH}_2\text{-NH}_2$), contains 46% of nitrogen. Various studies carried out to date have shown that urea treatment increases the feeding value of straw by increasing the digestibility and intake (Schiere et al. 1988). The conversion is not efficient when the ratio is low in available carbohydrate or other sources of energy for the bacteria, or when urea is added to a ration that is already fairly rich in protein (Rai et al. 1989).

In developing countries, substantial emphasis is put in crop cultivation to feed a large and growing number of human populations from limited available arable lands. Urea

treatment of low quality straw has been used mainly on experimental basis in developing countries. However, it is widely recognised that this technology offers very good prospects in these regions where large numbers of ruminant populations depend, to large extent, on crop residues. Urea is comparatively cheap, easily available and readily hydrolysed to NH_4 under the warm tropical climate. By and large, the use of urea to enrich the straws has remained confined to research and other government farms and has not yet made an impact on the farmers field. Large-scale application of this technology is likely to ultimately benefit the farmers. However, to date the work on urea application has been limited principally to nutrition trails involving cattle. Specifically, the potential application of urea in the yak has not been reported. The present study was, thus, conducted to investigate the suitability of the use of urea feeding in the yak.

Materials and methods

The basic straw used in this study was finger millet (*Elensine coracana*). Three male yak weighing 208, 236 and 280 kg were utilised in the feeding trials. Three feeding trials were conducted on consecutive months, each trial spanning 30 days. Faecal and urine samples were collected on the last seven days of each trial period. The first trial was conducted on chaffed finger millet straw (FMS) without any supplementation (Phase I). The second trial was conducted by supplementing the FMS with urea at the rate of 200 g urea/30 kg FMS (Phase II). The third trial was conducted on FMS treated with 400 g urea for every 30 kg FMS (Phase III). Earlier reports (Pal et al. 1999a; Pal et al. 1999b; Pal et al. 1999c) revealed that the dry matter intake in yak is approximately 1.5% of live weights of animals consuming 7–8 kg of FMS per day. In the present study, the 7–8 kg of the treated FMS provided approximately 50 g urea/day per animal in Phase II and about 105 g urea/day per animal in Phase III. This amount is small in comparison to the recommendation for cattle of 4 kg/100 kg of air-dried straw (ICAR 1985). As urea use in yak feeding had not been tried, treatment with high amount of urea was avoided in the present study. This paper presents results comparing phases I and II with those of phase III. The effect on digestibility, on strained rumen liquor (SRL) and blood serum was also studied. Total N_2 , concentration of NH_4N_2 and total volatile fatty acids (TVFA) in SRL and urea, total NH_4N_2 (Conway Micro Diffusion Method) and glucose in blood serum were estimated using methods described by Briggs et al. (1957), AOAC (1984) and Chaudhury (1989), respectively. Statistical analysis was carried out according to the methods of Snedecor and Cochran (1967).

Results and discussion

The chemical compositions of the FMS in the three phases viz. untreated FMS, treated by 200 g/30 kg straw and by 400 g/30 kg straw, respectively, are presented in Table 1 and those of faecal samples are summarised in Table 2.

The average body weight (BW) changes in the three phases of feeding were -2.33, -1.7 and -1.3 kg, respectively. The maximum loss of BW of one yak in Phase III was -13 kg. Only

one yak gained weight in Phase III by 11 kg. The intake figures (in kg per 100 kg dry matter) are presented in Table 3. The CP percentages in the three phases were 6.19, 10.00 and 15.42, respectively. The rest of the chemical constituents showed some variations, which could be attributed to the fact that the lots of FMS used were procured from different sources. The average excretion of all the nutrients was very variable.

Table 1. Chemical composition of untreated and treated finger millet straw (FMS) (% on dry basis).

	Phase I	Phase II	Phase III
Crude protein (CP)	6.19	10.00	15.42
Ether extract (EE)	0.72	2.00	1.88
Crude fibre (CF)	27.48	29.63	27.25
Nitrogen free extract (NFE)	50.01	46.88	43.49
Total ash (TA)	15.60	11.49	11.96
Insoluble ash (IA)	3.26	2.63	3.68
Calcium (Ca)	0.94	0.87	1.22
Phosphorus (P)	0.17	0.26	0.47

Table 2. Chemical composition of faeces in the three metabolic collections in three yak in each trial (% on dry basis).

Animals	CP	EE	CF	NFE	TA	IA	Ca	P
Untreated FMS								
1	11.88	0.53	15.53	35.85	36.21	25.82	1.33	0.26
2	9.56	0.53	18.00	37.58	34.33	24.50	1.41	0.32
3	8.31	0.94	15.32	33.00	42.43	28.52	1.33	0.35
Average	9.92	0.67	16.28	35.48	37.66	26.28	1.36	0.31
Treated FMS (200 g/30 kg)								
1	11.21	1.80	19.69	38.14	29.15	18.48	1.94	0.50
2	11.44	2.25	22.61	39.42	24.28	14.53	1.79	0.47
3	11.03	1.99	23.37	34.41	29.20	16.23	1.75	0.44
Average	11.23	2.01	21.89	37.32	27.54	16.41	1.83	0.47
Treated FMS (400 g/30 kg)								
1	21.50	2.50	20.97	28.96	26.07	15.48	2.57	0.95
2	15.50	1.19	24.21	18.50	40.60	29.99	1.47	0.62
3	15.20	2.16	23.64	30.94	28.01	15.95	2.06	1.09
Average	17.40	1.95	22.94	26.13	31.56	20.47	2.03	0.88

CP= crude protein, EE= ether extract, CF= crude fibre, NFE=nitrogen free extract, TA= total ash, IA= insoluble ash, Ca=calcium, P= phosphorus.

The intakes of DM (kg/100 kg BW) were not significant but when compared on total intake basis, irrespective of the BW, there were significant differences among animals but not between the treated and untreated FMS. The average daily intakes of DM were 3.08, 4.16 and 3.68 kg, respectively, in the three phases (Table 3).

Table 3. Intake of dry matter, kg/100 kg body weight (BW), in the three phases of the trial.

Animals	Phase I	Phase II	Phase III
1	1.56	1.41	1.55
2	1.73	1.80	1.79
3	1.33	1.30	1.37
Average	1.54	1.50	1.57

Urea incorporation did not affect the DM, EE and NFE digestibility. The CP and CF digestibility were significantly different ($P < 0.05$). The CP was digested at a significantly higher rate but there was no significant difference between the 200 and 400 g incorporation/30 kg FMS. The digestibility of CF was adversely affected by incorporation of urea. Untreated FMS recorded higher digestibility and there was no difference between the treated and untreated FMS (Tables 4 and 5).

Table 4. Digestibility coefficients of dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF) and nitrogen free extract (NFE) in the three rations (%).

Animals	Phase I	Phase II	Phase III
DM			
1	59.40	60.75	64.80
2	59.57	60.01	59.35
3	56.93	55.21	59.52
Average	58.63	58.65	61.22
CP			
1	21.92	55.99	50.92
2	37.56	54.26	59.14
3	42.18	50.62	59.96
Average	33.89	53.62	56.67
EE			
1	70.06	64.67	53.18
2	70.24	55.00	74.27
3	43.77	55.44	59.51
Average	61.36	58.37	62.32
CF			
1	77.01	73.92	72.91
2	73.48	64.49	63.89
3	75.99	64.86	64.88
Average	75.49	67.76	67.23
NFE			
1	70.84	68.07	76.56
2	69.62	66.38	82.71
3	71.58	67.13	71.20
Average	70.68	67.19	76.82

Table 6 reveals that the rations differ significantly ($P < 0.01$) in terms of digestible CP (DCP) although the total digestible nutrient (TDN) values were not significantly different among the rations. Urea supplementation increased the N_2 utilisation only.

Table 5. The mean 'F' values of digestibility coefficients (%) of different nutrients in the three rations.

	Phase I	Phase II	Phase III	'F' (2, 4)
Dry matter (DM)	58.63	58.65	61.22	2.23 ^{ns}
Crude protein (CP)	33.89 ^a	53.62 ^b	56.67 ^b	10.6*
Ether extract (EE)	61.36	58.37	62.32	0.89 ^{ns}
Crude fibre (CF)	75.49 ^a	67.76 ^b	67.23 ^b	12.35*
Nitrogen free extract (NFE)	70.68	67.19	76.82	5.08 ^{ns}

ns = not significant; * = significant at $P < 0.05$; superscripts in the same row differ from each other.

Table 6. Digestible crude protein (DCP) and total digestible nutrient (TDN) content, kg/100kg dry matter (DM), in the three rations.

Animals	Phase I	Phase II	Phase III	F (2, 4)
DCP				
1	1.35	5.60	7.82	
2	2.32	5.43	9.12	
3	2.61	5.06	9.25	
Average	2.09 ^a	5.36 ^b	8.74 ^c	106.53**
TDN				
1	59.07	62.32	63.26	
2	58.48	59.62	65.64	
3	60.00	58.20	60.41	
Average	59.18	60.04	63.10	3.07 ^{ns}

ns = not significant; ** = Significant at $P < 0.01$; superscripts in the same row differ from each other.

The N_2 balance in the untreated FMS was marginally positive and was not significantly different from the mean value of +8.76 in the treated FMS (200 g/30 kg straw). The 400 g urea supplementation per 30 kg FMS gave a significantly ($P < 0.05$) higher balance (+33.73) of N_2 than the two other feeding regimens. The calcium balance was positive but appeared to be very erratic. Untreated and treated (400 g/30 kg FMS) straws gave almost similar balances and differed significantly from 200 g supplementation ration. The phosphorus balance was positive and remained unaffected (Table 7).

Rumen liquor obtained by stomach tube from all the three animals in all the three feeding regimen viz. untreated FMS and treated FMS (200 g/30 kg and 400 g/30 kg) on three consecutive days were analysed for total N_2 , ammonia N_2 , and TVFA. The results are summarised in Table 8.

Table 7. Nitrogen, calcium (Ca) and phosphorus (P) balances (g/day).

Animals	Phase I	Phase II	Phase III	F (2, 6)
N ₂ (g/day)				
1	-3.17	+3.67	+17.91	
2	+5.61	+15.33	+12.90	
3	+4.86	+7.27	+40.39	
Average	+2.43 ^a	+8.76 ^a	+33.73 ^b	16.28*
Ca (g/day)				
1	11.59	2.13	9.56	
2	13.53	6.26	26.03	
3	11.03	2.90	14.49	
Average	12.05 ^a	3.76 ^b	16.69 ^a	8.18*
P (g/day)				
1	1.89	1.80	4.16	
2	1.38	2.96	9.13	
3	0.50	2.18	1.06	
Average	1.26	2.31	4.78	2.08 ^{ns}

ns = not significant; * = Significant at P<0.05; superscripts in the same row differ from each other.

Table 8. Total N₂ (mg/100 mL strained rumen liquor (SRL)), ammonia N₂ (mg/100 mL SRL) and total volatile fatty acids (TVFA) (mmol/100 mL SRL) in three rations.

	Days	Phase I			Phase II			Phase III		
		Animals								
		1	2	3	1	2	3	1	2	3
Total N ₂	Day 1	29	48	46	39	69	51	70	73	79
	Day 2	35	46	50	47	60	70	55	52	72
	Day 3	32	49	52	48	56	67	58	50	77
	Mean	32	48	49	45	62	63	61	58	76
Ammonia N ₂	Day 1	3.5	4.1	15.4	2.8	3.6	9.5	1.9	3.0	8.4
	Day 2	2.8	6.0	10.0	3.1	4.5	2.8	3.1	5.2	8.4
	Day 3	5.1	6.5	11.2	4.3	7.2	9.6	2.7	6.3	7.0
	Mean	3.8	5.5	12.2	3.4	5.1	7.0	2.6	4.8	7.9
TVFA	Day 1	9.5	12.2	10.0	8.4	10.4	10.0	8.2	9.0	8.0
	Day 2	12.3	11.8	12.8	11.2	10.0	10.2	11.1	8.5	9.6
	Day 3	11.3	12.0	11.5	10.0	8.9	11.4	10.0	9.8	10.5
	Mean	11.0	12.0	11.4	9.9	9.8	10.5	9.8	9.1	9.4

From the serum of the experimental yak, ammonia N₂, urea and glucose were estimated for three days and data are presented in Table 9.

Table 9. Serum ammonia N₂, urea and glucose concentrations (mg/100 mL) in three treatments.

	Days	Phase I			Phase II			Phase III		
		Animals								
		1	2	3	1	2	3	1	2	3
Ammonia N ₂	Day 1	1.88	0.42	1.12	3.29	0.49	0.74	3.08	0.56	1.12
	Day 2	2.10	4.06	0.49	2.70	3.57	0.70	2.60	3.01	1.40
	Day 3	1.35	2.38	0.35	0.68	0.70	0.35	1.05	1.40	1.82
	Mean	1.78	2.29	0.65	2.22	1.59	0.60	2.24	1.66	1.45
Urea	Day 1	15.0	17.8	30.0	6.8	12.7	25.5	15.0	14.2	30.0
	Day 2	12.8	18.7	34.5	9.0	9.5	25.5	14.5	16.3	30.0
	Day 3	20.0	30.0	39.5	10.0	19.2	24.8	20.0	27.5	32.3
	Mean	15.9	22.2	34.7	8.6	13.8	25.3	16.5	19.3	30.8
Glucose	Day 1	50	49	77	57	49	77	71	37	67
	Day 2	45	51	72	59	54	69	45	49	50
	Day 3	50	38	77	52	48	72	46	42	61
	Mean	48	46	75	56	50	73	54	43	59

The differences among the animals were highly significant (P<0.01) in all the parameters except in the case of ammonia N₂. As would be expected, the total N₂ concentration in SRL increased with urea incorporation. This was not the case for ammonia concentrations. TVFA decreased significantly with the incorporation of urea in FMS. Ammonia N₂ and glucose in serum were not affected, but urea increased significantly in serum. The result that untreated straw had a higher concentration of urea was unusual and could not be explained (Table 10).

Table 10. The means with 'F' values in the three rations for total N₂, ammonia N₂ and total volatile fatty acids (TVFA) in strained rumen liquor (SRL), and ammonia N₂, urea and glucose in serum.

	Phase I	Phase II	Phase III	F (2, 22)
Total N ₂ in SRL (mg/100 mL)	43.0 ^a	56.3 ^b	65.1 ^c	35.62**
Ammonia N ₂ in SRL (mg/100 mL)	7.18	5.16	5.11	1.78 ^{ns}
TVFA in SRL (mmol/100 mL)	11.49 ^a	10.06 ^b	9.41 ^b	8.78**
Ammonia N ₂ in serum (mg/100 mL)	1.57	1.47	1.78	0.20 ^{ns}
Urea in serum (mg/100 mL)	24.26 ^a	15.89 ^b	22.2 ^c	10.44**
Serum glucose (mg/100 mL)	56.6	59.7	52.0	2.41 ^{ns}

ns = not significant; ** = Significant at P<0.01; superscripts in the same row differ from each other.

It is concluded that urea treated of FMS at the rate of 200 and 400 g per 30 kg FMS did not increase the DM intake perceptibly. The average intake of 1.54 kg/100 kg BW of the untreated FMS came down to 1.50 kg/100 kg BW when treated with 200 g/30 kg and increased to 1.57 kg when treated with 400 g/30 kg FMS. The DM digestibility of the rations (58.6, 58.6 and 61.2%, respectively) was almost similar. CP digestibility (%), DCP (kg/100 kg DM) and N₂ balances were significantly affected by treatment. The CP digestibility progressively increased from 33.9 to 53.6% and then to 56.7%. Likewise the DCP (kg/100 DM) increased from 2.09 to 5.36% and then to 8.74%. N₂ balance of 8.76 g in 200 g treated

ration was not significantly different from untreated value of 4.55, while N₂ balance in 400 g treated ration greatly increased the value to 33.7 g/day. The responses of the individual animals were high and in many cases were not uniform. The results of the biochemical characterisation of the SRL and serum also revealed the differences among the animals. The treatment of FMS with urea affected total N₂ and TVFA in SRL and urea in serum. Ammonia N₂ in SRL and serum glucose remained unaffected. Comparison of the results obtained could not be compared with literature values, as probably this is the first study of urea feeding in yak in India. Only one reference could be obtained from work in China but due to language barrier it could not be examined in sufficient detail.

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Peptide and amino acid metabolism in the gastro-intestinal tract of yak

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Summary

The present experiment was conducted to quantify the net fluxes of both free (FAA) and peptide amino acids (PAA) across the mesenteric and stomach portions of the portal-drained viscera (PDV) of three yak cows (weighing 172.3 ± 18.6 kg) fitted with sampling catheters in the portal vein, mesenteric artery and mesenteric vein prior to its convergence with the gastrosplenic vein. Blood flow was determined by measuring the dilution of para-aminohippurate (PAH) infused constantly into a distal mesenteric vein. Amino acids in the deproteinised plasma were analysed before and after acid hydrolysis. The increased amino acids after acid hydrolysis were considered as PAA. Portal blood flow was 389 L/h or 2.32 L/h kg body weight (BW), of which 37% was contributed by the mesenteric vein. There was net appearance of a large quantity of PAA across PDV, which accounted for 92% of the total nonprotein amino acid flux. Net release of PAA and FAA in stomach-drained viscera (SDV) accounted for 78% and 42% of the net release in PDV, respectively. These results suggest that, in yak, the peptide possibly to be the primary form of amino acid absorption, and that the stomach area probably to be the major site of peptide absorption.

Keywords: Amino acids, flux, mesenteric, peptide, stomach, yak

Introduction

Recent studies suggest that the peptide may be the primary form of amino acid absorption in the ruminants (Koelln et al. 1993; Webb et al. 1993; Seal and Parker 1996), and that the site of absorption of these peptides does not appear to be the mesenteric viscera but, instead, appears to be the stomach viscera (Webb et al. 1993). Further *in vitro* studies suggest that the forestomach has the ability to absorb dipeptide (Matthews and Webb 1995), and that the omasal epithelium contains mRNA that codes for protein capable of di-, tri-, and tetrapeptide transport (Matthews et al. 1996; Pan et al. 1997). Considerable evidence has been accumulated regarding the absorption of dipeptides and tripeptides. However, the nutritional and metabolic significance of peptide absorption is not fully understood, and the extent to which intact peptides may be absorbed into the blood stream is controversial

(Webb et al. 1993; Backwell et al. 1997; Han 1999), especially in ruminants. The objective of the present study was to quantify the *in vivo* fluxes of both FAA and PAA across the mesenteric and stomach portions of the PDV in yak.

Materials and methods

Three nonpregnant yak cows in late stage of lactation (1 kg of daily milk production) and at an average body weight of 172.3 ± 18.6 kg, were surgically fitted with in-dwelling catheters in the portal vein, the anterior mesenteric vein. The diet used consisted of field pea straw (500 g/kg), maize (335 g/kg), fish meal (80 g/kg), soy bean meal (70 g/kg), bone meal (10 g/kg) and salt (5 g/kg), and contained 133.5 g crude protein (CP) and 9.62 MJ ME/kg dry matter (DM). Each animal was offered 2.0 kg DM/day, which was calculated to meet maintenance energy (ME) requirement according to Han and Xie (1991), and this allotment was offered to the animals at 08:00 am and 20:00 pm in two equal meals.

On the sampling day, a primed (20 mL), and then a continuous mesenteric venous infusion of PAH (6%, wt/vol., pH 7.4) was initiated via the distal mesenteric vein catheter to determine portal and mesenteric venous blood flows. One hour after the infusion, simultaneous arterial, portal and mesenteric venous blood samples were collected slowly into syringes containing heparin. For PAA and FAA analyses, six mL of blood from each vessel were taken six times at 2-h intervals; and for PAH analysis, an additional 1.5 mL of blood was collected at 1-h intervals.

In the laboratory, packed cell volume was determined. Huntington (1982) described that the concentration of PAH in the whole blood was measured colorimetrically. In later analysis, pooled plasma samples were obtained from the six individual samples within yak and within sampling site, and deproteinised by the addition of an equal volume of sulfosalicylic acid (20%, wt/vol.). Precipitated protein was removed by centrifugation at $15,000 \times g$ for 15 minutes at 4°C. The supernatant was divided into two portions, one of which was hydrolysed in 6 N HCl at 110°C for 24 h. Both samples were then subjected to analysis on an amino acid analyser (HITACHI 835-50). The difference before and after hydrolysis was considered as PAA.

Portal and mesenteric blood flows were calculated as described previously (Han et al. 1997). Net fluxes of FAA and PAA across PDV and mesenteric-drained viscera (MDV) were calculated as described by Seal and Parker (1996). Stomach flux was calculated as the difference between portal and mesenteric fluxes. Mean net fluxes across portal, mesenteric and gastrosplenic veins were compared using Student's T-tests; a probability of $P \leq 0.05$ was used to test for significance.

Results

The portal and mesenteric blood flows averaged 389 L/h and 144 L/h or 2.32 L/h kg BW and 0.84 L/h kg BW, respectively. The mesenteric blood flow accounted for 37% of the

portal blood flow. Large differences (for all amino acids, $P < 0.001$) between FAA and PAA concentrations in the same blood vessel were found, and the concentrations of PAA were 5.6, 5.1 and 5.2 times higher than that of FAA in the portal, mesenteric veins and artery, respectively.

Net release of FAA across the gastro-intestinal tract was minimal (Table 1) and the net portal flux was 40 g/day, of which 23 g came from the mesenteric viscera and 17 g from the stomach viscera, accounting for 58.5% and 41.5% of the total FAA appearing in the portal vein, respectively. Net release of PAA is shown in Table 1. The net flux of total PAA across the portal-drained viscera was 459 g/day, of which 358 g came from the stomach viscera and 101 g came from MDV, accounting for 78% and 22% of the total PAA, respectively. Compared with FAA, PAA appeared the major contributor to the total amino acid flux. Unlike FAA, almost all PAA in the portal vein came from the stomach viscera.

Discussion

It is accepted that peptide absorption is an important physiological process in ruminants and may constitute the primary source of absorbed amino acids. In the present study, the net appearance of small peptides in the portal circulation accounted for 92% of total amino acid flux. This result was in good agreement with the results (87% to 90%) observed by Koelln et al. (1993); Webb et al. (1993) in steers and sheep, but was somewhat higher than those (63% to 70%) reported by Koelln et al. (1993) and Seal and Parker (1996) in steers. The origin of these peptides could not be determined by the techniques applied in the present study. Absorption from the lumen may be a logical explanation for the net appearance of these peptides in the portal circulation. Another explanation might be that these peptides are possibly the result of synthetic activity in the tissues drained by the portal vein. A combination of these explanations seems likely. The net flux of FAA across PDV in the present study was low as compared with PAA; this result was also similar to the observations of Koelln et al. (1993) and Webb et al. (1993). An explanation may be that the tissues between the lumen and the portal vein used a large part of the absorbed FAA as indicated by Seal and Parker (1996) and MacRae et al. (1997).

In the present study, the total appearance of FAA and PAA in the portal vein was 500 g/day, which was 1.9 times the intake of dietary protein. This result agrees with the observation by Koelln et al. (1993). Based on the evidence that chemical deproteinisation overestimates the PAA concentration in the plasma (Bernard and Rémond 1996; Backwell et al. 1997), it is suspected that the high flux of peptides may be due to the effect of the deproteinisation procedure (Neutze et al. 1996; Backwell et al. 1997). However, Seal and Parker (1996) reported that, even after the treatments of both chemical deproteinisation and physical filtration, the PAA flux still accounted for 63% of the net portal appearance of total amino acids. In their study, the net flux of free and peptide amino acids also was 1.6 times the protein intake. In young calves, the total appearance of FAA and PAA was as high as 438 g/day even when the animals were deprived of feed for 72 h (Koelln et al. 1993). These observations suggest that a large part of the small peptides might be the degradation

products resulting from the turnover of tissue protein in the gastro-intestinal tract, spleen, pancreas or a combination of these organs.

Table 1. Blood flow (L/h) and net fluxes (g/d) of free (FAA) and peptide amino acids (PAA) across the portal (PV), mesenteric (MV) and stomach (SV) viscera of yak cows fed a concentrate-straw diet at maintenance level (mean \pm SE).

	Free amino acids			Peptide amino acids			Difference
	PV	MV	SV	PV	MV	SV	
Blood flow	388.9 (3.9)	143.9 (3.5)	245.0 (3.9)	388.9 (3.9)	143.9 (3.5)	245.0 (3.9)	
Plasma flow	240.7 (3.3)	89.4 (2.9)	151.3 (3.1)	240.7 (3.3)	89.4 (2.9)	151.3 (3.1)	
Aspartate	1.9 (0.6)	1.4 (0.6)	0.6 (1.8)	42.3 (1.5)	8.5 (1.0)	33.8 (1.5)	a, b, c, d
Threonine	4.0 (1.4)	1.0 (0.5)	3.3 (0.9)	27.8 (2.0)	4.5 (1.1)	23.3 (1.3)	a, c, d
Serine	2.1 (0.7)	1.5 (0.6)	0.6 (1.2)	32.0 (1.8)	4.3 (0.9)	27.7 (1.3)	a, c, d
Glutamate	4.4 (0.7)	1.3 (1.0)	3.1 (0.8)	63.0 (2.6)	0.3 (0.4)	63.3 (1.5)	a, c, d
Glycine	4.3 (1.0)	2.5 (0.8)	1.8 (1.8)	38.6 (1.6)	16.0 (1.4)	22.6 (1.1)	a, b, c
Alanine	5.8 (0.8)	4.1 (1.1)	1.7 (1.2)	22.3 (1.5)	6.0 (1.0)	16.3 (0.9)	a, c, d
Valine	2.8 (0.8)	1.6 (1.0)	1.2 (0.6)	27.7 (1.6)	4.0 (1.2)	23.7 (1.2)	a, c, d
Methionine	0.6 (0.4)	0.4 (0.5)	0.2 (0.9)	3.2 (0.6)	1.1 (0.5)	2.1 (0.4)	
Isoleucine	1.6 (0.6)	0.9 (0.4)	0.7 (0.8)	21.5 (1.4)	6.8 (1.2)	14.6 (1.3)	a, c, d
Leucine	1.4 (0.6)	1.8 (1.2)	-0.4 (2.2)	39.4 (1.3)	7.2 (0.9)	32.2 (1.2)	a, c, d
Tyrosine	1.4 (0.5)	0.1 (0.4)	1.4 (1.1)	18.4 (1.6)	4.0 (1.1)	14.4 (0.69)	a, c, d
Phenylalanine	3.2 (0.7)	1.8 (1.1)	1.5 (0.5)	21.2 (1.5)	5.0 (0.8)	16.3 (1.0)	a, c, d
Lysine	1.4 (0.6)	1.6 (0.7)	-0.2 (1.8)	32.7 (1.8)	6.6 (0.8)	26.1 (1.5)	a, c, d
Histidine	1.5 (0.6)	0.7 (0.7)	0.8 (1.2)	11.4 (1.4)	2.0 (0.8)	9.3 (1.2)	a, c,
Arginine	3.0 (0.7)	2.2 (1.2)	0.7 (0.9)	22.6 (1.3)	3.4 (1.4)	19.3 (0.9)	a, c, d
Proline	0.8 (0.4)	1.0 (0.9)	-0.1 (1.1)	32.0 (1.8)	3.4 (0.7)	28.7 (1.6)	a, c, d
Essential amino acids (EAA)	19.4 (1.5)	11.6 (1.6)	7.7 (1.7)	207.5 (3.2)	59.4 (2.2)	148.1 (2.3)	a, b, c, d
Non-essential amino acids (NEAA)	20.9 (1.2)	11.7 (1.3)	9.3 (0.9)	252.1 (2.9)	41.9 (1.5)	210.2 (2.0)	a, b, c, d
Total amino acids (TAA)	40.2 (1.4)	23.3 (1.4)	16.9 (1.3)	459.5 (3.1)	101.2 (2.7)	358.3 (2.2)	a, b, c, d

a, b and c indicate significant differences ($P < 0.05$) between free and peptide amino acid fluxes in the portal, mesenteric and stomach viscera, respectively. d indicates significant difference ($P < 0.05$) in flux of peptide amino acid between mesenteric and stomach viscera.

The recent observation that the stomach region of the gastro-intestinal tract may be an important site of peptide absorption is quite significant. The work of Webb et al. (1993) indicated that 86% and 90% of PAA in the portal veins of sheep and calves, respectively, came from the stomach viscera. Seal and Parker (1996) measured the net flux of PAA using the fractionation method separating a low-molecular-weight (<10,000 Da) peptide fraction by filtration and then HPLC (high performance liquid chromatography) to separate four fractions containing peptides with molecular weights of <1500 Da. They found that some 40% of portal PAA were from MDV, and suggested that the remaining 60% were from the stomach viscera, and that the stomach tissue may be a major site of peptide absorption. In

the present experiment, 78% of the absorbed PAA were from the stomach viscera. The ability of the forestomach to absorb small peptide has been demonstrated by *in vitro* (Matthews and Webb 1995) and *in vivo* (Bernard and Rémond 1999) studies.

Although only 8% of the total amino acids appearing in the portal vein were FAA, 42% of these FAA were from the stomach viscera. From this percentage it could be said that the stomach might be an additional site of amino acid absorption. Webb et al. (1993) also indicated that 22% and 11% of the total FAA appearing in the portal vein of calves and sheep, respectively, were from the stomach viscera. Matthews and Webb (1995) shown *within vitro* procedures using both radiolabelled and nonradiolabelled methionine the potential for amino acid absorption across the mucosal tissues of rumen and omasum. In addition, Leibholz (1971) observed transfer of histidine, glycine, lysine and arginine across isolated ruminal epithelial tissues of sheep. These observations suggest that the forestomachs of ruminants have the ability to absorb amino acids.

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Grass and legume variety trials in eastern Tibet

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Summary

Approximately 28% (42.5 million hectare (ha)) of Qinghai's high elevation rangelands are considered to be in deteriorated condition. Re-vegetation of these degraded rangelands requires improved forage grasses adapted to the harsh environment of the Qinghai-Tibetan Plateau. In May 1999, high altitude grass varieties of *Poa*, *Festuca*, *Deschampsia*, *Bromus*, *Stipa*, *Agrostis*, *Dactylis*, *Phleum*, *Elymus*, and *Agropyron* and legume varieties of *Medicago*, *Onobrychis*, *Astragalus*, and *Lupinus* were planted at two replicate locations in Guoluo Prefecture: Dawu Seed Farm (3512 metres above sea level (masl)), Maqin County and Jimei Research Area (3968 masl). Each location contained 75 plots (3 m by 3 m) with varieties randomised within 3 blocks, 25 plots to a block in a randomised block design. Seedlings were monitored for establishment (year 1) and survival over winter (year 2). Seeds were also analysed in the laboratory for germination characteristics. There were significant differences ($P < 0.0001$) among varieties for seedling establishment and over-winter survival. Differences between locations were significant ($P < 0.0001$). Coefficients of determination (R^2) ranged between $R^2 = 0.78$ and 0.80 . Eight grass varieties survived over winter at optimal levels, in descending order: *Festuca ovina*, *Deschampsia caespitosa*, Tibetan Mixture, *Festuca rubra* var. *rubra*, *Poa pratensis* var. *alpinum*, *Bromus inermis*, *Poa compressa* and *Poa pratensis*. Laboratory germination tests did not accurately predict success in the field. Differences in performance within species points out that different genotypes (seedlots) of the same species can perform very differently. Implications for re-vegetation of degraded sites in Guoluo are discussed.

Keywords: Forages, Qinghai, rangeland, re-vegetation, sheep, subalpine, yak

Introduction

Approximately 28% (42.5 million ha) of Qinghai's high elevation rangelands are considered to be in deteriorated condition (Lang et al. no date). Erosion features known as

* The Qinghai Livestock Development is a joint venture of European Union and People's Republic of China.

'black beach' or 'black soils' are common, many of which cover 20 to 30 ha and more. Black beach forms when the native *Kobresia* sod is broken and wind, water and the freeze-melt cycle induces the loose sod to erode down slopes, thus exposing the dark, black soil beneath. Pikas (*Ochotona* spp.), small burrowing lagomorphs, further complicate the situation by competing with livestock for the native rangeland forages. Furthermore, livestock production in Qinghai is hampered by the lack of adequate forages in both quantity (maintenance rations) and quality (production and reproduction rations). In order to remedy the condition of these rangelands and improve the nutrition of yak and sheep, adapted forage grasses are needed for re-vegetation (Limbach 1998; Sheehy 1998).

Townships involved with the Qinghai Livestock Development Project in Guoluo Prefecture extend from about 3000 to over 6000 masl. These rangelands constitute a valuable and albeit impoverished forage base for yak, sheep and horses, and the subsistence livelihood of the Tibetan herders. Weight loss and mortality among livestock are common occurrences in most years, especially in late winter and early spring when livestock condition is at its lowest, the forages in the winter pastures are overused, and heavy snowfalls, known as 'snow disasters', cause high livestock mortality. Re-vegetation of these impoverished rangelands will greatly increase the livestock production, improve the grazing during winter, help reduce the disastrous effects of heavy snows, and aid in improving the livelihoods of Tibetan herders in the project area. Improved forage grasses are required for the re-vegetation and rehabilitation of these degraded rangelands to improve livestock performance and to renew and re-stabilise degraded sites.

This field trial was implemented to test the adaptation and suitability of 25 improved varieties of perennial forages for rangeland re-vegetation in Guoluo.

Materials and methods

In 1999, 19 improved varieties of perennial grasses and legumes were imported from Pickseed Canada, Vancouver, British Columbia (Table 1). Six other varieties, two grasses, three legumes, and Tibetan Mixture were previously imported from Germany in 1996 (Archer 1996). In late May and early June, these varieties were planted at field sites near Dawu, Maqin County and Jimei, Dari County. In July 1999, these varieties were also tested for germination characteristics in the laboratory of the Qinghai Academy of Animal and Veterinary Sciences (QAAVS).

Species screening: emergence, establishment and over-winter survival

A randomised block design experiment was set up at Dawu (ca. 3659 masl) and Jimei (ca. 3963 masl). At each location, an area of about 50 m by 20 m was ploughed, cultivated, and 75 plots (3 m by 3 m) were arranged in 3 blocks of 25 each; blocks = replicates ($n = 3$). Each block consisted of five rows of five, 3×3 plots. All interspaces between rows and blocks were 1 m wide. Plots within rows were adjacent to each other and had no interspaces between

them. Varieties were planted into these plots in a completely randomised arrangement within block. Due to different sized seedlots and large differences in seed sizes, different seeding rates were used (Table 1). Seedling densities for emergence (early June 1999), establishment (first week of September 1999), and over-winter survival (middle May 2000) were sampled using a 0.0625 m² quadrat (25 cm × 25 cm), one randomly placed quadrat per plot, excluding 0.5 m around the edge of each plot. Results (seedling densities, individuals per quadrat) were assessed using a 2-way analysis of variance (ANOVA). Since survival over-winter is the most important characteristic of a variety once it has established in the first year, only over-winter survival is discussed in this paper.

Table 1. Grass and legume species names, variety number, seeding rate and source of seeds.

No.	Species names	G plot ¹	Source
Grasses			
1	<i>Poa alpina</i> var. mantelsaatgut	18	Germany
2	<i>Poa compressa</i>	18	Canada
3	<i>Poa pratensis</i> var. alpina	18	Canada
4	<i>Poa pratensis</i>	18	Canada
5	<i>Stipa viridula</i>	36	Canada
6	<i>Koeleria cristata</i>	18	Canada
7	<i>Dactylis glomerata</i>	36	Canada
8	<i>Bromus inermis</i>	36	Germany
9	<i>Festuca ovina</i>	36	Canada
10	<i>Festuca rubra</i> var. rubra	36	Canada
11	<i>Agrostis alba</i>	20	Canada
12	<i>Phleum pratense</i>	18	Germany
13	<i>Phleum pratense</i>	18	Canada
14	<i>Deschampsia caespitosa</i>	18	Canada
15	<i>Deschampsia caespitosa</i>	18	Germany
16	<i>Trisetum flavescens</i>	27	Canada
17	<i>Agropyron smithii</i>	36	Canada
18	<i>Agropyron dasystachyum</i>	36	Canada
19	<i>Elymus trachycaulus</i>	36	Canada
20	Tibetan Mixture ¹	18	Germany
Legumes			
1	<i>Medicago sativa</i> var. Anik	18	Germany
2	<i>Onobrychis sativa</i> var. Remont	36	Canada
3	<i>Astragalus cicer</i>	18	Canada
4	<i>Medicago sativa</i> var. Able	18	Canada
5	<i>Lupinus luteus</i>	36	Germany

1. Tibetan Mixture comprised 11 grasses: *Agrostis canina*, *A. gigantea*, *A. capilaris*, *Dactylis glomerata*, *Deschampsia flexuosa*, *Festuca rubra* var. rubra, *F. rubra* var. communtata, *Poa alpina*, *Phleum pratense*, *Poa annua*, *Trisetum flavescens* and 5 forbs: *Achillea millefolium*, *Anthyllis vulneria*, *Lotus corniculatus*, *Trifolium hybridum* and *T. repens*.

Laboratory germination

Three replicates of 100 seeds of each variety were sown into flats filled with sterilised, washed sand and kept well watered during the course of the investigation. Seeds were incubated in a dark growth chamber at 20°C for 28 days. Counts of emergent seedlings were made daily. Maximum percentage of germination (G_{max}) was assessed.

Statistical analyses were performed using SPSS 8.0 for Windows, Chicago, IL, USA. Correlation was used to assess the association among laboratory germination and seedling performance in the field. Mean comparisons were determined using the Least Significant Difference test, $\alpha = 0.05$.

Results and discussion

The 1999 summer-growing-season was a good period for seedling emergence and establishment. Rainfall was well above the long-term average, which ranges between 500 and 600 mm, in the project area (Buda, Veterinary Station, Dari County, personal communication). All varieties were able to fully express their establishment vigour.

Grass seedling densities (number of seedlings/quadrat) for establishment in 1999 were high at both locations: mean = 69.0 each at Dawu, 57.7 each at Jimei. Legume seedling densities were lower than grasses; mean = 18.7 each at Dawu, 17.3 each at Jimei, though the two *Medicago* varieties appeared to be most successful legumes with means of about 36 each at Dawu and 20 each at Jimei. *Lupinus luteus* was the first of the legumes to emerge but hares heavily grazed it. This caused all *Lupinus* seedlings to die out before the end of the growing-season.

In 2000, there were significant differences in over-winter survival amongst varieties ($P < 0.0001$) and between sites ($P < 0.0001$); the location by variety interaction term was also significant (Table 2). Differences between locations probably were due to differences in rainfall and soil fertility; these differences, however, are not biologically significant. Significant differences among varieties would be expected in a field test of so many species and varieties. The coefficient of determination (R^2) shows that the ANOVA model fits the data well and explained about 80% of the variation; only 20% of the variation was attributable to unexplained sources.

Table 2. Response of over-winter seedling survival (number/quadrat) to variations in location and variety.

Source	Df	SSIII	MS	F	P>F
Location	1	74.907	74.907	31.125	<0.0001
Variety	24	661.333	27.556	11.450	<0.0001
Location × Variety	24	196.427	8.184	3.401	<0.0001
Error	100	240.667	2.407		

Model $R^2 = 0.795$

Over-winter seedling survival densities are presented in Table 3. Eight grass varieties survived at optimal levels: *Festuca ovina* (variety 9) at 112 individuals/m², *Deschampsia caespitosa* (variety 14) at 96 individuals/m², Tibetan Mixture (variety 20) at 88 individuals/m², *Festuca rubra* var. *rubra* (variety 10) at 80 individuals/m², *Poa pratensis* var. *alpinum* (variety 03) at 72 individuals/m², *Bromus inermis* (variety 08) at 72 individuals/m², *Poa compressa* (variety 02) at 64 individuals/m², and *Poa pratensis* (variety 04) at 56 individuals/m² (Table 3).

Table 3. Seedling survival densities (individuals/m²) in May 2000 at Dawu, Maqin County and Jimei, Dari County, Guoluo Prefecture, Qinghai, P.R. China.

Varieties	Dawu	Jimei	Variety	Dawu	Jimei
9	4	10	15	2	2
14	6	6	5	1	2
20	2	9	12	2	1
10	3	7	17	2	1
3	3	6	7	1	1
8	2	7	16	1	0
2	2	6	1	0	0
4	3	4	21	0	0
6	1	5	22	0	0
13	2	3	23	0	0
19	2	3	24	0	0
18	2	3	25	0	0
11	3	1			

These species-varieties are apparently well adapted to establishment and survival in the severe high altitude environment of Guoluo Prefecture. These characteristics make them prime candidates for rangeland re-vegetation and improvement projects in Guoluo and the Qinghai-Tibetan Plateau. It is not surprising that these same species are distributed worldwide at high altitudes on all the major continents of the Northern and Southern Hemispheres (Wu and Wang 1999). It would be interesting to compare these imported varieties with local seed sources of the same species.

The results obtained with the Tibetan Mixture should be qualified. It was difficult to tell which individuals were from the mixture and which were volunteers from the local seed bank. In addition, no legumes emerged from the Tibetan Mixture.

Survival of even the most robust varieties was low, compared to the numbers of seedlings that had established at the end of the 1999 growing-season (Limbach 2000). This may be due to a number of factors:

1. Livestock trespassed on both experimental areas between October 1999 and May 2000. There was evidence of yak trespass at Jimei and sheep trespass at Dawu. Therefore, grazing by livestock may have killed large numbers of the grass and legume seedlings that had established in 1999 by pulling them out of the ground.
2. Desiccation of seedlings over the 1999/2000 winter, which was drier than normal (Buda, personal communication), may have caused a large number of seedlings to die.

3. As a consequence of a below-normal, dry winter, the soils of the field sites were not afforded the ameliorating effect of a cover of snow. This may have exacerbated seedling die-off by frost action pushing the weakly rooted seedlings out of the soil. Furthermore, the valley of Dawu is much more open and broad than the valley in Jimei. This may account for the poorer survival at Dawu (Table 3) even though Dawu had better seedling establishment than Jimei in the autumn of 1999 (Limbach 2000). The soils at Dawu did appear to be looser, fluffier, and less compact than the soils at Jimei.

The varieties are ranked in descending order in Table 4. Low rankings refer to good performance (high seedling densities or high G_{\max}) while high rankings refer to poor performance (low seedling densities or low G_{\max}). Correlation coefficients (R) show unpredictable relationships between survival and establishment ($R = -0.47$; $P = 0.018$) and survival and maximum germination percentage, G_{\max} ($R = 0.10$; $P = 0.628$). These characteristics, obtained in the greenhouse and laboratory, did not predict over-winter success in the field.

Table 4. Rankings of varieties according to maximum germination (laboratory), field establishment (September 1999), and over-winter survival (June 2000).

Varieties	Scientific Name	G_{\max}	September 1999	Survival 2000
9	<i>Festuca ovina</i>	11	8	1
14	<i>Deschampsia caespitosa</i>	18	4	2
20	Tibetan Mixture	9	9	3
10	<i>Festuca rubra</i> var. <i>rubra</i>	17	14	4
3	<i>Poa pratensis</i> var. <i>alpina</i>	14	6	5
8	<i>Bromus inermis</i>	8	19	6
2	<i>Poa compressa</i>	20	1	7
4	<i>Poa pratensis</i>	23.5 ¹	22	8
6	<i>Koeleria cristata</i>	2	12	9
13	<i>Phleum pratense</i>	6	7	10
19	<i>Elymus trachycaulus</i>	25	10	11
18	<i>Agropyron dasystachyum</i>	3	13	12
11	<i>Agrostis alba</i>	19	2	13
15	<i>Deschampsia caespitosa</i>	16	16	14
5	<i>Stipa viridula</i>	22	17	15
12	<i>Phleum pratense</i>	13	11	16
17	<i>Agropyron smithii</i>	21	20	17
7	<i>Dactylis glomerata</i>	12	5	18
16	<i>Trisetum flavescens</i>	5	3	19
1	<i>Poa alpina</i> var. <i>mantelsaatgut</i>	23.5 ¹	25	20
21	<i>Medicago sativa</i> var. <i>Anik</i>	10	15	21
22	<i>Onobrychis sativa</i> var. <i>Remont</i>	7	23	22
23	<i>Astragalus cicer</i>	15	21	23
24	<i>Medicago sativa</i> var. <i>Able</i>	4	18	24
25	<i>Lupinus luteus</i>	1	24	25

1. Ties in ranking within columns were averaged.

Testing different varieties within species

Different varieties (genotypes) within species and different seedlots within species may perform very differently. When a sample of particular species fails in field tests, it does not mean that all varieties of that species will fail. This fact is well demonstrated in the present study by the performance of varieties numbers 14 and 15, different genotypes of *Deschampsia caespitosa* (Table 5). Screening plant materials at the species level is severe as a selection criterion and will greatly limit the amount of plant materials for future selection.

Table 5. Mean over-winter seedling density (number/quadrat) of two varieties of *Deschampsia caespitosa*.

Variety	Dawu	Jimei
DECA 14	5.67	6.33
DECA 15	1.67	2.00

Differences are significant ($P < 0.001$) using Chi-Square Goodness of Fit.

A caveat on rangeland re-vegetation

The next step is to extend these results to reseedling of degraded range sites. Restoring the productive capacity of degraded ranges, however, is a major undertaking anywhere it is contemplated. It is expensive in terms of time, money and manpower. And it is *very* risky. This latter point cannot be over-emphasised. When the plant community has been degraded or transformed to a lower ecological-successional status, an ecological threshold has been crossed. This ecological threshold is a theoretical demarcation between plant communities of different successional status, a more desirable plant community and a less desirable one. In the degraded state, the plant community is one of lower ecological status and poorer in terms of grazing. Once the rangeland has changed to a lower, less productive status, however, it is very difficult to return it back to a more productive status. Direct manipulations, like re-vegetation with modern equipment and rehabilitation techniques, are required to restore a productive plant community. But what happens if after all the effort the seeding fails due to the vagaries of the climate and environment?

At present, a typical reseedling operation as performed in Guoluo by the QAAVS using traditional agronomic techniques may consist of four or more separate operations, each one requiring tractor and implement to manipulate the entire operational area: initially ploughing, then harrowing, followed by broadcast seeding and application of fertiliser, then packing or tamping the soil, and a second fertiliser application in another month or so. The cost of such a reseedling operation is about 120–150 RMB Yuan/mu (US\$ 1 = 8.2 Yuan during this study; 1 hectare = 15 mu) (Ma Yushou, personal communication). This is approximately twice the cost of similar operations in countries such as Australia and the United States. The cost effectiveness of reseedling operations could be considerably improved by utilisation of an inter-seeding, rangeland drill. Reseeding with a rangeland drill can be effected in a single pass, thus greatly reducing the costs in fuel and manpower.

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Availability and utilisation of shrubs as protein sources for yak grazing on alpine meadow on the Qinghai–Tibetan Plateau, P.R. China

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Summary

The distributions of alpine shrubs on Qinghai–Tibetan Plateau of China are reviewed, and the relationship between the alpine shrubs and yak is discussed. Based on the nutritional evaluation and economic analysis, the utilisation of shrubs as protein supplements for the yak grazing on the alpine meadow is proposed.

Keywords: Grazing, protein supplement, shrubs, yak

Introduction

In alpine pastoral areas, legumes are very limited in pastures. As a result, protein deficiency is one of the major constraints to the improvement of productivity of grazing livestock in these areas, i.e. for yak and sheep (Li and Song 1984). Previous studies have shown that supplementation of grazing yak and Tibetan sheep with protein-rich feeds can significantly improve their body condition and performances (Zhang et al. 1999). From ecological and economic points of view, due to the high protein content, nutritive value and availability, shrubs are likely to be the best protein supplements for yak grazing on the alpine meadow (Long et al. 1999, unpublished). Although a lot of researches on using of shrubs as protein supplements for grazing animals have been done in tropical and sub-tropical conditions (Everist 1969; Akkasaeng et al. 1989; Goodchild 1990; Raghavan 1990; Rajaguru 1990; Smith 1992; Topps 1992; Bonsi 1995; Robert 1997), there is very little information on evaluation of alpine shrubs as supplement feeds for grazing yak. This article reviews information available on this subject and concludes that more attention should be paid to the role of shrubs as an alternative protein feed source on the Qinghai–Tibetan Plateau.

Alpine shrubs on the Qinghai–Tibetan Plateau

Shrub is a kind of plant combining the characteristics of tree and grass. Shrubs have been defined as the leaves, shoots and sprouts, including tender twigs and stems of woody plants, which are cropped to a varying extent by domestic and wild animals (Robert 1997). Alpine shrub is an important type of vegetation, which almost covers the whole transition areas from forest to alpine meadow on the Qinghai–Tibetan Plateau in China, where the altitude varies from 3000 to 5000 metres above sea level (masl), with a total area of about 116,400 km² located in the north-eastern Plateau, including the south-eastern Qinghai Province, the north-western Sichuan Province, western Gannan Prefecture of Gansu Province and the north-eastern Tibetan Autonomous Region (Wu 1980).

In the eastern part of these areas, i.e. the north-eastern Sichuan Province, the western Gannan Prefecture and the south-eastern Qinghai Province, the shrub land occupies the shadow slopes of the mountains between 3800 and 4200 masl at the elevation. The major species of alpine shrubs are generally *Dasiphora fruticosa*, *Salix alpina*, *Sibiraea angustata*, *Spiraea alpina*, *Rhododendron capitatum*, *R. przewalskii* and *R. anthogonoides*. Moreover, *Dasiphora fruticosa*, *Caragana jubata* and *C. microphylla* can be found occasionally on the sunny slopes of the mountains.

In the western part of the areas, i.e. the north-eastern Tibetan Autonomous Region, the alpine shrubs grow on the higher altitude lands, normally above 4000 masl, where the *Dasiphora fruticosa* extensively covers the sunny slopes while the *Caragana jubata* and *C. microphylla* occupy the shadowed slopes. *Rhododendron capitatum* and *Salix alpina* occasionally also appear on the shadowed parts of the mountains.

The distribution of alpine shrubs is quite similar to the distribution of the yak (Table 1). The great overlap of the distribution between the shrubs and the yak shows that the shrubs play an important role in yak farming system on Qinghai–Tibetan Plateau of China.

Table 1. Distribution of alpine shrubs and the overlap with that of yak.

Species	Distribution	Overlap with yak distribution
<i>Dasiphora fruticosa</i>	Along north-eastern Qinghai–Tibetan Plateau	+++
<i>Salix alpina</i>	East and west parts of north-eastern Qinghai–Tibetan Plateau	++
<i>Sibiraea angustata</i>	East part of north-eastern Qinghai–Tibetan Plateau	+
<i>Spiraea alpina</i>	East and west parts of north-eastern Qinghai–Tibetan Plateau	++
<i>Rhododendron capitatum</i>	South-eastern Qinghai Province and Gannan Prefecture	+
<i>R. przewalskii</i>	South-eastern Qinghai Province and Gannan Prefecture	+
<i>R. Anthogonoides</i>	Occasionally found on some parts of north-eastern Qinghai–Tibetan Plateau	+
<i>Caragana jubata</i>	West parts of north-eastern Qinghai–Tibetan Plateau	++
<i>C. Microphylla</i>	Occasionally found on some parts of north-eastern Qinghai–Tibetan Plateau	+

+ = much; ++ = very much; +++ = extremely much.

Relationship between alpine shrubs and yak on the Qinghai–Tibetan Plateau

Alpine shrub lands are the habitat and grazing lands for the yak in summer and sometimes in the winter as well. As such, they play an essential role in yak production (Long et al. 1993; Zhou et al. 1994; Yu et al. 1999; Zhang et al. 1999). There is substantial interaction between the alpine shrubs and the grazing yak on Qinghai–Tibetan Plateau. The effect of this interaction depends a lot on the grazing strategy.

Under appropriate grazing strategy, the moderate activity of the animals can promote the re-growth of the shrubs; therefore, the total phenological biomass and the quality of shrubs are enhanced because of more leaves and tender stems. In turn, the better nutrient supply from shrubs can increase the intake, digestibility and metabolism by the animal; thus the animals' performances are improved. However, inappropriate grazing strategy can destroy the balance of soil–plant–animal ecosystem, with important implications for the shrub growth and animal production. With high grazing intensity, all of the foliage and tender stems of shrubs are eaten by the animals, which result in the disappearance of some shrubs, the destroyed community structure of plant, and the lowered yield of herbage in the sward. Eventually the animal production is badly reduced and the serious problem of soil erosion creeps in (Zhou et al. 1994). On the other hand, if the grazing intensity is too low, the re-growth of shrubs cannot be stimulated efficiently, and the productive potential of plants cannot be achieved. Thus, animal productivity can be considerably affected by the imbalance in both nutrient supply and feed deficiency.

Clearly, the harmony between the alpine shrubs and the grazing yak is very important in this ecosystem. Shrub–yak integration must be maintained to optimise the productivity of the yak production system.

Roles of alpine shrubs in yak farming system on the plateau

At present, on the Qinghai–Tibetan Plateau, most Tibetan yak herders adopt a seasonal rotational grazing system, under which they divide the pastures into summer and winter grazing lands. The winter grazing lands are herb lands, which are reserved with fence and mainly utilised in cold and dry season (from November to April) when forage availability becomes low. The summer grazing lands are shrub lands, the communal areas in which the yak can graze in wet and warm season (from June to October). When the yak are herded on the shrub lands in the wet season, they browse the foliage and tender stems of shrubs together with grazing the grass under and around the shrubs. In this way, the animals are able to get sufficient feeds with better-balanced nutrients (Long 1999).

For the grazing animals, the benefits from shrub (browse) feeds include increased metabolism energy intake, increased nitrogen intake, feed efficiency, improved palatability, increased availability of minerals and vitamins, improved rumen function, better animal performance and a laxative influence on the alimentary system (Robert 1997). An

important attendant advantage is a lowered cost of feeding because energy and protein supplements do not have to be purchased. The herdsmen's experiences also suggest that the yak cows graze on shrub lands during reproductive period show higher heat rate. With regard to the soil-grass-animal ecosystem, the benefits of feeding shrubs to animals are mainly decreased grazing pressure on the grasslands, reduced overgrazing rate and retarded degradation of the grasslands, and, in the long run, the balance in the ecosystem is maintained gradually, and the feed resources are utilised sustainably.

In yak framing system on Qinghai-Tibetan Plateau, shrubs possess multiple roles. They can be used as the fuel by the nomadic herders in summer when they travel a long distance from their houses to herd their animals on the shrub lands. They are also used as the fence materials by the herders to protect the winter grazing lands and to make enclosures or shelters for the animals at night. Moreover, some herders use the shrubs as construction materials to make the shelters for the animals in winter.

All considered, the shrubs are much more important as protein supplements for the yak grazing on the grass meadow. Grassland scientists or animal nutritionists ignored this point, and only limited literatures on the values of the shrubs as animal feeds are available in this region, even in the whole country. Therefore, the importance of shrubs as supplementary feeds for yak has to be emphasised in terms of their nutritive value and economical benefit in animal production.

Nutritive value of alpine shrubs as animal feeds

The nutritive value of forages depends on the voluntary intake of the feed consumed and the quantity of dry matter and, in turn, the dry matter content in terms of dietary energy, proteins, minerals and vitamins. Ultimately, much will depend on the actual quantity of feed eaten by the animal on a daily basis (Robert 1997). With shrubs, the quantity eaten by the yak is relatively small. When compared with herbs, the acceptance or edibility (palatability) of shrubs is much lower, partly due to the physical characteristics (hairiness, bulkiness), and partly because of the presence of compounds, which may affect taste and appetite (volatile oils, soluble carbohydrates and anti-nutritional factors). However, the shrubs do considerably contribute to the compositions of daily diets of grazing yak. Pu (1999) reported that on the *Dasiphora fruticosa* shrub lands, shrubs account for 19.2% of diets of yak. Other researchers have also provided evidences that indicate some alpine shrubs form major components of diets of grazing yak (Long et al. 1993; Zhou et al. 1994; Yu et al. 1999; Zhang et al. 1999).

Although information about the digestibility (degradability) of nutrients in shrubs are not available, the results from chemical analysis on the compositions of some shrubs can provide us clues on the quality of shrubs as animal feeds. Available information shows that the CP, NFE, Ca, P and ME in alpine shrubs are quite high, even higher than those of the major native herbages (Table 2). It is clear that shrubs have a distinct advantage over alpine grasses and sedges due to their superior nutritional values. Some non-legume shrubs such as *Hippophae tibetica* and *Myrmanica germanica* are comparable to the legume herbages; some legume shrubs such as *Caragana jubata*, *C. microphylla* and *C. pygmaea* are excellent

alternatives to the legume herbage. Therefore, from a nutritional point of view, shrubs can be the protein supplements for grazing yak on alpine grass meadow.

Economic benefit of shrub feeds as protein supplements

As has been alluded to, one of the major beneficial effects of shrubs as supplement feeds for grazing yak is the lowered cost of feeding compared to a system in which feed supplements are purchased. The overall goal is to improve animal productivity based, as much as possible, on locally available resources with a minimum cost.

Table 2. Chemical compositions of foliage and stem of some alpine shrubs and major herbage on the Qinghai–Tibetan Plateau (dry matter (DM) basis).

Species	DM (%)	CP (%)	NFE (%)	CF (%)	Ash (%)	Ca (%)	P (%)	ME (MJ/kg)
Shrubs								
<i>Caragana jubata</i>	91.48	10.72	39.31	28.81	9.15	1.67	0.133	8.91
<i>C. microphylla</i>	92.95	12.51	41.21	28.63	7.67	1.29	0.116	9.24
<i>C. pygmaea</i>	90.07	21.75	42.16	24.76	7.82	1.16	0.47	9.84 ¹
<i>Dasiphora fruticosa</i>	91.70	10.38	47.84	24.76	6.66	0.99	0.134	9.21
<i>D. giabra</i>	92.06	9.69	46.15	28.12	6.25	1.27	0.119	9.12
<i>Spiraea alpina</i>	91.66	10.46	47.74	26.68	4.39	0.91	0.086	9.46
<i>Hippophae tibetica</i>	91.96	23.64	47.11	12.98	3.76	0.90	0.304	10.60
<i>Myrmanica germanica</i>	91.15	12.01	48.70	12.01	18.11	4.15	0.127	8.49
Grasses								
<i>Elymus nutans</i>	90.29	8.47	36.09	37.03	6.65	0.33	0.129	7.60
<i>Poa pratensis</i>	92.56	6.88	50.80	27.94	5.60	0.28	0.11	9.11
<i>Roegneria Nutans</i>	88.68	6.47	36.99	37.95	5.43	0.22	0.202	8.70
<i>Stipa aliena</i>	86.86	10.18	34.82	32.86	5.63	0.45	0.185	8.15
<i>Agropyron cristatum</i>	91.37	9.40	27.20	43.40	10.97	0.26	0.20	6.42
Sedges								
<i>Carex kansuensis</i>	92.81	8.56	53.18	23.07	5.81	0.55	0.094	9.37
<i>Kobresia capillifolia</i>	85.93	11.56	36.40	30.47	5.96	0.59	0.118	9.31

DM = dry matter; CP = crude protein; NFE = nitrogen free extract; CF = crude fibre; Ca = calcium; P = phosphorus; ME = metabolic energy.

Sources: Jia (1987); Chen (1994).

On the Qinghai–Tibetan Plateau, as free-ranging animals, the yak graze on the natural grasslands whole year round, and they cannot get sufficient protein from natural herbage (Long 1995). However, it is hard for these animals to obtain protein and energy supplements from outside the system due to the remoteness, poor infrastructure, financial limitation and labour deficiency in the yak farming areas. Fortunately, the yak can freely browse the protein-rich shrubs without extra financial input at anytime of the year.

Therefore, from an economic point of view, it is feasible to develop shrubs as protein feeds in yak farming system.

Closing remarks

Although shrubs are ideal protein supplements for the grazing yak as far as nutritive values and economic benefits are concerned, some potentially dangerous compounds (anti-nutritional factors) have been found in some of these fodder shrubs. Tannins are the most important ones in alpine shrubs (Long 1999). It is, therefore, necessary to carry out more research to determine appropriate methods of alleviating these deleterious effects in order to upgrade the quality of protein of these feeds. For optimum utilisation of shrubs, it is essential that details of agronomic characteristics, palatability and nutritive values of the important species are determined through both chemical analysis and *in sacco* and *in vitro* methods.

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Seasonal changes in forage nutrients and mineral contents in water resources, forage and yak blood

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Summary

This paper reports results of a study conducted to investigate the concentrations of seven mineral elements in yak blood, forage and water resources around the Qinghai Lake in Qinghai Province in different seasons. Meanwhile, the nutritional compositions of the forage were also surveyed. The results suggest that the mineral elements and the forage nutrients change in a seasonal pattern. In yak blood, the sodium (Na) concentration varies from 0.291 to 0.034 mg/mL, and this is lower than the normal value. In the forage, the ratio calcium (Ca) to phosphorus (P) is 4.06–7.47:1 and potassium (K) to Na 30–27:1. These results indicate that the nutrition of the yak in the area is deficient in Na but high in K. For the withered forage sampled in February, the protein content is only 31.14% of the total protein in the forage growing at puerile stage in June. The severe loss of protein by 68.9% and decrease of effective nutrients in the wintered forage are considered to be the reasons resulting in the poor condition of yak in winter and spring seasons.

Keywords: Forage, mineral elements, nutrients, water, yak

Introduction

Yak grazing under prolonged harsh conditions have developed the adaptability to tolerate the poor fodder supply in winter and spring. However, little is known about their nutritional status in terms of mineral contents in both yak blood and the animal's feed and water supply in different seasons. The understanding of changes of mineral elements in forage, water resources and yak blood, and the changes of nutritional compositions in the forage can be useful pieces of information in developing nutritional management strategies. The objective of this study was to investigate the concentration of seven mineral elements in yak blood, forage and water resources in different seasons of the year.

Materials and methods

Background of the study sites

The experiment was done in the state-owned Sanjiaocheng sheep farm located in Gangcha County of Qinghai Province, near the Qinghai Lake. The altitude is above 3200 metres above sea level (masl), the annual average temperature -6°C , the verdant period of 108 days, the annual rainfall 370 mm, and the annual evaporation 1607 mm.

Sampling date

The study was done from October 1997 to June 1998 and samples were collected in June, October and February. These three sampling dates were the periods corresponding to growth stage of forage in puerile, on growth end and in withered time, respectively.

Measurements

The forage samples were collected by multiple dotted cutting and then mixed for measuring the nutrients. Ten healthy yak were selected randomly and then earmarked to sample the blood during the three measurement periods for mineral content analyses. Seven kinds of mineral elements in yak serum, water resources and the forage were measured.

Results and discussion

Crude protein in the forage is 15.22% at its puerile stage and 6.83% at growth stage. At withered stage, it is 4.74%, which is 31.14% of that at the puerile stage. The crude fat content changes in the same pattern. Crude fibre, ash and Ca increase with forage growth. The extractions of non-nitrogen vary from 43.79–51.71%. The content of Ca and the ratio of Ca to P change as crude fibre (Table 1).

Table 1. Nutrient composition of forages studied(%).

Period	DM	CP	F	CF	NNE	Ash	Ca	P	Ca/P
June	89.91	15.22	3.83	20.38	43.79	5.88	0.65	0.16	4.1:1
October	92.91	6.83	2.98	23.93	51.71	6.38	0.93	0.14	6.0:1
February	92.07	4.74	2.85	26.00	48.99	8.31	1.04	0.16	7.4:1

DM= dry matter; CP = crude protein; F = fibre; CF= crude fat; NNE= non-nitrogen extracts; Ca= calcium; P= phosphorus.

The mineral contents in water resources and forage vary seasonally and they could meet yak growth and development requirements, except Na that is lower than yak requirements (Tables 2 and 3). The highest Na content per kilogram forage is 244.6 mg, and per mL water is 155.2 μg . This is far lower than the normal requirement (Qiu et al. 1989). In addition, the K:Na ratio in the forage (30–27:1) is higher than the normal range of 5:1 (Jiang et al. 1993).

Table 2. Mineral contents in water resources ($\mu\text{g}/\text{mL}$).

Date	Cu	Fe	Zn	Ca	Mg	K	Na
June	0.002	0.023	0.031	8.64	169	0.612	155.2
October	0.001	0.050	0.010	24.05	0.376	2.29	8.16
February	0.004	1.500	0.080	92.5	3.14	0.58	0.41

Cu = copper; Fe= iron; Zn = zinc; Ca = calcium; Mg = magnesium; K = potassium; Na = sodium.

Table 3. Mineral contents of forages studied (mg/kg).

Period	Cu	Fe	Zn	Ca	Mg	K	Na
June	6.93	430.4	29.7	4960	2050	7562	244.6
October	2.37	280.4	9.6	6450.5	163.5	3525	120
February	8.08	334.5	37	24150.6	6625	2932.5	107

Cu= copper; Fe = iron; Zn = zinc; Ca = calcium; Mg = magnesium; K = potassium; Na = sodium.

The mineral contents in yak blood vary between seasons except copper (Cu) ($P < 0.01$) whose levels in serum are not significantly different among the three sampling periods and are lower than the normal range of 0.8–1.2 $\mu\text{g}/\text{mL}$. Na level is also much lower than the normal range of 3.3–3.4 mg/mL (Ni and Wang 1994). The other mineral concentrations are in the normal range for yak growth and development (Table 4).

Table 4. Mineral content of yak serum ($\mu\text{g}/\text{mL}$).

Period	No.	Cu	Fe	Zn	Ca	Mg	K	Na
June	10	0.374	3.168 ^c	2.765 ^{bc}	99.743 ^a	29.199 ^{ab}	170.19 ^c	291.045 ^a
October	10	0.404	5.865 ^a	7.618 ^a	87.858 ^b	31.983 ^a	279 ^a	200.816 ^b
February	6	0.405	4.249 ^b	2.814 ^b	85.5 ^{bc}	26.799 ^{bc}	195.45 ^b	34.10 ^c
F-test	10	$P > 0.05$	$P < 0.01$	$P < 0.01$	$P < 0.01$	$P < 0.01$	$P < 0.01$	$P < 0.01$

Cu = copper; Fe = iron; Zn zinc; Ca = calcium; Mg = magnesium; K = potassium; Na = sodium; Superscripts in the same column differ from each other.

From the results of the study, it is suggested that the supplementary mineral blocks containing Na, P and Cu should be given to yak in the area to facilitate normal yak growth and development. This should also improve the overall health of the animals (Zhang 1998).

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Utilisation of alpine shrubs in yak farming in Qilian mountain regions

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Summary

The seasonal dynamics of concentrations of total extractable condensed tannins (CT), crude protein (CP), acid detergent fibre (ADF) and crude ash (CA) of five shrubs growing in the Qilian regions of Gansu Province, China, were determined from June to September 1999. The dry matter (DM) disappearance of these shrubs in yak rumen was also estimated by *in sacco* method. The results show that different feeding shrubs have different concentrations of CT, which declined markedly with the degree of maturity. The concentrations of CT vary between 58.1–102.6 g/kg DM in June. In August, almost all decline to below 50 g/kg DM. The CP contents, ranging from 13.9–23.3% in August, also decline with the degree of maturity. The changes in the ADF and CA contents are inconsistent among the shrubs, except for the gradual increase of ADF in *Caragana jubata* and gradual decrease in *Spiraea alpina* throughout the season. DM digestibility of *Salix mystillacea*, *Spiraea alpina* and *Dasiphora fruticosa* are 69.9%, 63.0% and 65.7%, respectively, in August, which is higher than that in June and July. There are negative relationships between 48 h DM degradability and the CT content ($r = -0.24$, $P > 0.05$) and ADF content ($r = -0.065$, $P > 0.05$), respectively. Based on this study, it is suggested that shrubs are good feed sources in the alpine region, primarily because of their high protein content, although the CT content has negative effect on the DM digestibility. It is suggested that the best utilisation season of shrubs should be after August.

Keywords: Alpine region, condensed tannins, shrubs, utilisation, yak

Introduction

Alpine shrub and grass tussocks are one of the main grazing pastures of yak in China. They cover about 116,400 km² and are mainly distributed in the area above the forest line at an altitude of 3000–4000 metres above sea level (masl). There are lots of edible shrubs for yak and Tibetan sheep in these areas. These include *Dasiphora fruticosa*, *D. glabra*, *Spiraea alpina*, *Caragana jubata*, *C. brevifolia*, *Salix alpina*, *S. bolia*, *S. cupularis*, *S. mystillacea*, *Lonicera syringantha* and *Hippophae tibetica*. They play an important role in reducing the grazing pressure on pastures and are an important source of protein for yak (Pu 1999). The calorific value of shrubs in alpine grassland has been reported to be much higher than that of herbs

(Long et al. 1993). However, most shrubs contain anti-nutritional components such as tannins (Jackson et al. 1996), which influence the palatability of shrubs. Consumption of a large quantity of feeds rich in condensed tannins (CT) has been shown to reduce feed intake (Barry 1989). But low concentrations of CT will increase the quantities of essential amino acids (EAA) absorbed from the small intestine of ruminants without affecting volatile fatty acid (VFA) (Waghorn et al. 1987). This is due to CT-protein bonds being stable in rumen (pH 5.5–7.0), but unstable in abomasums (pH 2.5–3.5) and in small intestine (pH 8.0–8.5) for releasing the protein (Johns and Mangan 1977).

Many researches have been done in tropical and sub-tropical regions in estimating the feeding value of shrubs rich in CT. However, little is known about the CT and the seasonal dynamics of nutrients of alpine shrubs. The objectives of this study were to measure the seasonal dynamics of total extractable CT, CP and ADF in the leaves of alpine feeding shrubs, and to determine the DM disappearance rate *in sacco* of these shrubs in yak rumen.

Materials and methods

Plant materials

Leaves were sampled from five native feeding shrubs on 20 June, 20 July, 20 August and 20 September 1999 from alpine shrubs and grass tussocks in the Tianzhu Tibetan Autonomous County of Gansu Province, China. The shrubs were *Dasiphora fruticosa*, *Spiraea alpina*, *Caragana jubata*, *Salix mystillacea* and *Hippophae tibetica*. Plant samples were oven-dried at 65°C for 48 h and milled through a 1.0 mm screen for chemical analysis and through a 2.5 mm screen for *in sacco* degradability study.

Experimental animals

Three young female yak fitted with rumen fistula were used in the study. The animals were fed twice a day on a diet consisting of 100% oats hay (CP content 6.3% and ADF 36.4%).

Determination of condensed tannins

Plant tissue (0.2–1 g fresh weight) was macerated in a glass homogenizer with 70% v/v acetone:water (tissue weight:volume, 1:3), containing 0.1% w/v ascorbic acid. The concentration of CT was measured following Vanillin-HCl method described by Broadhurst and Jones (1978). Catechin was used as the standard.

Chemical analysis

DM and CA contents were determined as described by Association of Official Agricultural Chemists (AOAC 1984). ADF was determined according to the method described by van Soest et al. (1991). CP was determined following Kjeldal method.

In sacco dry matter degradability analysis

Analysis was carried out according to the procedure described by Mehrez et al. (1977). Samples weighing 2.5 g were transferred into a nylon bag and incubated in three rumen fistulated yak for 48 h. On removal, nylon bag was thoroughly washed and dried at 65°C for 48 h for further analysis.

Results

The CP contents of all tested samples are very high, ranging from 8.6–17.2% in August but decline with the change of seasons. From June to September, the CP content of *Dasiphora fruticosa* declined by 69.9%, *Caragana jubata* by 49.4%, and *Hippophae tibetica* by 40.3%. There are no significant differences in CP contents among shrub species ($P>0.05$). The seasonal changes in the ADF contents are not consistent and remain between 20 and 30%, except for a gradual increase of ADF content in *Caragana jubata* and a gradual decrease in *Spiraea alpina* across the seasons. The concentrations of CA range from 3.1–5.9% and show no significant variations among seasons for all shrub species (Table 1).

Table 1. Crude protein (CP) and acid detergent fibre (ADF) contents of five alpine shrubs, % dry matter (DM).

Samples	CP				ADF			
	June	July	Aug.	Sept.	June	July	Aug.	Sept.
<i>Dasiphora fruticosa</i>	19.7	9.0	8.6	4.4	25.0	27.9	24.5	27.5
<i>Hippophae tibetica</i>	24.4	14.3	11.6	10.7	22.2	30.0	26.3	25.4
<i>Spiraea alpina</i>	29.3	22.7	17.2	15.9	21.5	18.2	19.4	21.2
<i>Salix mystillacea</i>	22.0	19.3	10.2	10.0	29.9	26.9	23.2	22.7
<i>Caragana jubata</i>	24.0	18.9	14.5	11.9	26.8	25.9	31.9	44.5

Tannins are plant polyphenols combining with proteins and other polymers such as cellulose and hemi-cellulose to form stable complexes. They are present in many shrubs and trees in tropical and sub-tropical areas. The data from present study demonstrate that alpine shrubs also contained CT (Table 2).

Table 2. Concentrations of condensed tannins (CT) of five feeding shrubs, g/kg dry matter (DM).

Samples	June	July	August	September	Average
<i>Dasiphora fruticosa</i>	74.8	71.9	40.5	30.0	54.3
<i>Hippophae tibetica</i>	102.6	80.8	57.6	27.3	67.1
<i>Spiraea alpina</i>	58.1	23.2	21.1	14.3	29.2
<i>Salix mystillacea</i>	91.2	72.3	47.7	22.9	58.5
<i>Caragana jubata</i>	69.5	47.2	38.6	13.3	42.2

The concentrations of CT in these shrubs vary among species. *Hippophae tibetica* has the highest content of CT in June (102.6 g/kg DM), while the rest of the species have less than

100 g/kg DM in June or 60 g/kg DM in August. The CT contents decline significantly with the maturity of shrubs.

Yak are the main consumers of alpine shrubs in the region of the study. In this study, the DM digestibility of these feeds range from 41.4–75.0% (Figure 1). The average DM digestibility of these shrubs across all the seasons is 67.4% for *Salix mystillacea*, 62.1% for *Spiraea alpina*, 45.5% for *Hippophae tibetica*, 55.1% for *Dasiphora fruticosa* and 50.1% for *Caragana jubata*.

Discussion

Edible plants play an important role in providing fodder for ruminants in most parts of the world. However, many species have evolved with chemicals (secondary compounds) to protect themselves from bacteria, insects, fungi and grazing animals. Condensed Tannins is one group of these chemicals. It may depress intake or utilisation of feed components (high tannin content), or may enhance feed nutritive value (low tannin content) (Barry et al. 1986).

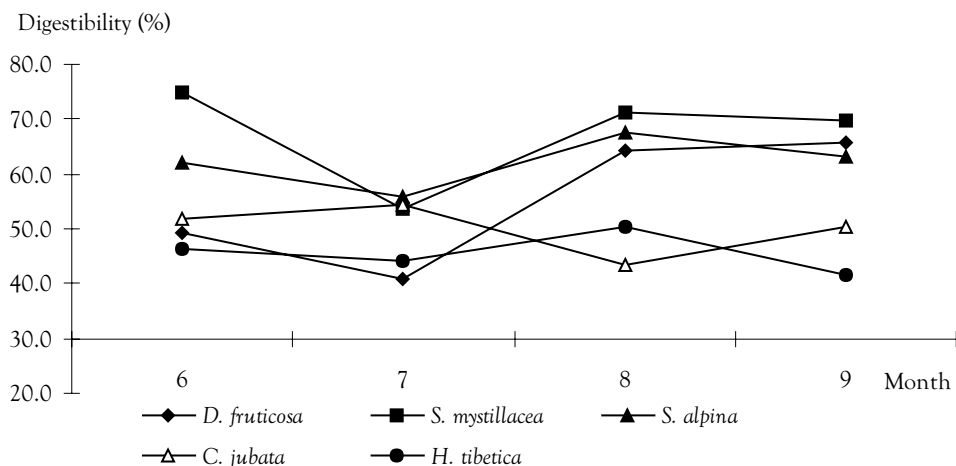


Figure 1. Dry matter (DM) digestibility of five alpine shrubs.

Condensed Tannins content determines whether a shrub can be used as an animal feed. Jackson et al. (1996) suggested that when CT is lower than 50 g/kg DM, the shrub could be edible or fed in medium quantities of the diet in supplementary feeding. In our study, the Condensed Tannins contents of the five main feeding shrubs are below 50 g/kg DM (except *Hippophae tibetica*) after August. These results indicate that yak could probably consume these feeds safely after August. During June and July, most of these shrubs have high CT contents. It is suggested that farmers should limit the grazing time of yak and Tibetan sheep in alpine shrub lands during these seasons.

There is high variability in the nutrient contents of shrubs attributed to within- or between species differences due to factors such as plant age and plant part, harvesting regimen, season and location. In the present study, the CP contents decreased as the plant matured. This result is similar to those reported for Greek browses (Khazaal et al. 1993), while the CP content (85.5 to 172.4 g/kg DM) in August is higher than that from Greek browses (70.5 to 132.9 g/kg DM). Chemicals like fibre and CT are known to influence DM degradability (Nordkvist and Aman 1986; Makkar et al. 1991). However, no significant relationship is found between the DM digestibility and ADF ($r = -0.065$, $P > 0.05$) and CT ($r = -0.24$, $P > 0.05$) in the present study.

Closing remark

Alpine shrubs are good supplementary feeds for yak, especially in the alpine regions where protein feed resources are very limited. However, in the present study, the amount of nutrients absorbed by yak was not determined. Thus, potential effect on productivity was not estimated. Research is needed to quantify the utilisation of alpine shrubs by yak, especially in the following aspects: a) voluntary consumption potential; b) potential digestibility; and c) ability to provide by-pass nutrients for absorption in the small intestine.

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Session IV: Reproduction and breeding

Monitoring of traits for yak and yak hybrids

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Summary

This paper briefly reviews breeding systems used for domestic yak and for yak hybrids. Traits for production and performance commonly selected by herders for breeding are highlighted. A simple recording system is then proposed that would allow breeding activities to be jointly monitored by herders and extension workers to reduce the presence of less desirable traits in herds and improve overall production and performance. The system would also permit basic information to be gathered on herd structures which can assist researchers and livestock extension workers to determine the extent of inbreeding within regions or areas of a country and better plan for appropriate interventions.

Keywords: Herd recording, inbreeding, trait, yak, yak hybrids

Introduction

Miller and Steane (1997) reported the distribution of domestic yak and yak hybrids as including the high-elevation areas of the Hindu Kush and Karakoram in Afghanistan and Pakistan; the Himalayas in India, Nepal and Bhutan; the Tibetan Plateau and Tien Shan mountains of north-western China; and western and northern Mongolia. Yak are also found in the adjoining areas of Russia and some of the central independent states of the former U.S.S.R. These animals provide pastoralists and agro-pastoralists living in these areas with a number of products (milk, meat, hair, hides and manure for fuel) and services (draft, packing and riding). They also serve important socio-economic (financial security) and cultural functions (status, dowry, religious festivals etc.).

A review of the papers presented at the two previous international congresses on yak (Rongchang et al. 1994; Rongzhen et al. 1997) and of the information contained in two key publications (Cai and Wiener 1995; Miller et al. 1997), as well as various other sources in the literature, indicate that inbreeding in the yak is of major concern, not only in terms of the adverse effects it can have on animal production and performance, but also its impact on genetic diversity. In this paper, general breeding systems and traits selected for production and performance by herders are briefly described. A simple recording system is then proposed which herders and extension workers could use as a start towards monitoring breeding activities at the herd level. The system will provide a tangible means by which herders can better differentiate among their animals, and thereby, justify their estimated

value for production, performance and market. Additionally, the system will facilitate the collection of baseline information on herd structures that can assist researchers when using modern diagnostic methods to evaluate or measure genetic diversity within populations. Information on herd structures can also be useful to livestock planners to determine appropriate interventions during disease outbreaks or natural disasters such as drought or severe winters.

Breeding systems

Herders traditionally breed yak or cross them with cattle to obtain offspring having traits that will maintain or enhance production and performance, in order to support their subsistence livelihoods and produce a commodity for existing markets. Strong emphasis is placed on producing offspring that are adapted to, and can survive in, the harsh environments in often-rugged terrain in the mountainous regions.

It is not within the scope of this paper to give a detailed discussion of all the breeding systems used by herders within and among different countries. However, the three systems described by Tshering et al. (1997) for Bhutan can be considered as being generally representative of systems used in other countries. The systems are: 1) pure line or straight breeding in which yak bulls (exchanged between breeding areas to avoid inbreeding) are mated with yak cows; 2) crossing of yak bulls with *Bos taurus* and *Bos indicus* cows and their hybrids; and 3) *Bos taurus* and *Bos indicus* bulls are crossed with female yak and their hybrids. Modifications of this system, along with information on different criteria for culling of animals and various schemes of backcrossing, can be found in several reports (Cai and Wiener 1995; Miller et al. 1997; Rongzhen et al. 1997; Wu 2000).

Herders attempt to improve performance traits of offspring through selection of bulls or females having those traits deemed important based on traditional knowledge and experience. In Nepal and Mongolia, for example, herders select breeding stock for preferred colours, markings and other characteristics including size, conformation, horn shape, milking ability and behaviour patterns (Joshi et al. 1994; Davaa 1997). Similar traits are considered in a list of traditional selection criteria for *Jiulong* yak compiled by Wu (1998), Wu (2000) based on Cai (1989) and Cai and Wiener (1995).

Hybridisation

Yak are thought to have been first crossed with Chinese yellow cattle more than 200 years B.C. (Rongchang et al. 1994). Hybridisation of yak and local/native or exotic cattle is carried out to obtain the benefit of heterosis in producing females with higher milk yields or larger animals for beef production or draft. Crossing of yak with one or more exotic cattle breeds (including Angus, Brown Swiss, Charolais, Hereford, Holstein, Jersey, Murray Gray and Simmental) has been carried out in most of the central Asian countries where yak are native (Paudyal 1986). Yak hybrids in Nepal are reported as being better adapted to the intermediate zone between cattle and yak habitats and are, therefore, able to utilise grazing

areas too low in elevation for yak, but too high for cattle (Robinson 1992, cited in Joshi et al. 1994). Male hybrids are commonly used for work. In China, for example, first crosses of yak females are mated with local bulls and the reciprocal crosses are widely used for draft or packing (Cai and Wiener 1995).

The crossbred F_1 of either sex is widely accepted to be superior to its parents in terms of growth and productivity. However, a drawback commonly cited is that crossbred animals are less adaptable to environments in higher elevations, especially during winter when supplements are required (Rongchang et al. 1994; Wu 1998). Shijian and Weisheng (1997) reported that hybrid F_1 offspring are not resistant to the harsh conditions over 3000 metres above sea level (masl). Joshi et al. (1994) stated that in Nepal F_2/F_3 offspring have little value and are usually slaughtered shortly after birth, whereas in India, farmers tend to keep animals belonging to F_2/F_3 generations, and F_4 onwards, although they are less productive and, therefore, not remunerative (Pal et al. 1994). Hybridisation may not be practised in certain areas, due to hybrids carrying the stigma that the milk and meat is of inferior quality to pure yak, and male offspring are infertile (Gyamtsho 1996; Tshering et al. 1997). Yak hybrids (F_1 and subsequent generations) are reported to produce less undercover or fine hairs (Pal 1997). Selection traits for animals to be mated will depend on projected use of offspring, but are similar to those mentioned for yak. Bulls used for hybridisation with female yak should have a high production potential, but be of smaller size to avoid calving difficulties (Pal et al. 1994).

Inbreeding

As with any species, proper breeding practices are necessary to maintain or improve levels of performance (milk and meat production), reproduction, suitability for work (draft, packing and riding), fitness (stamina) and disease resistance. However, use of the same yak male for several years to breed the same females, or hybridisation of yak with cattle through a number of generations beyond F_1 is not uncommon (Pal et al. 1994). Despite herders' intentions to employ sound breeding methods, this is often not possible. Replacement for males are normally chosen from among the sons of the currently used bull, generally from his own herd or from a relatively small group of herds with which he is associated. Competition among bulls for females results in the most aggressive and fertile male siring the most offspring. This process inevitably leads to inbreeding. The rate of inbreeding is likely to be more rapid in small herds or small herd groups using fewer bulls than larger herd units (Wiener 1997). Additionally, one has to recognise the herder's approach to breeding from a practical standpoint. His or her goal is to obtain as many new calves per breeding season as possible, even if an animal does not possess the desirable level of heterozygosity, which does not imply that it is not an economic investment (Pal et al. 1994).

Numerous papers highlighting the problem of inbreeding in yak herds can be found in the documents cited earlier. Inbreeding has been reported as being a particular problem in Bhutan, Nepal and India, whereas in the Hunza region of Pakistan and remote areas of Afghanistan, herds are thought to be less inbred (Cai and Wiener 1995). Miller and Steane (1997), although recognised that inbreeding exists in certain yak populations, caution that

additional studies and more accurate data are required to better assess the extent to which inbreeding poses a problem in countries and in which specific areas or pockets.

The main impact of inbreeding is reduced heterozygosity at the animal and herd level, resulting in lower animal performance. Adverse effects can be readily observed in terms of an animal's physical size and conformation. Inbreeding can produce animals lacking the stamina to survive in harsh environments and extreme temperatures at higher altitudes, particularly during winter months. Improper mating can result in development of overly large or deformed udders, making females more prone to injuries and reducing suckling or milking ability. Additionally, inbreeding can cause a lack of pigmentation around the eyes or on the mussel, leaving animals without protection against the effects of solar radiation. Use of overly aggressive sires can result in offspring being predisposed to fighting, increasing the risk of injuries to themselves and others. Aggressive animals are more difficult to handle, making them less suitable for work, thereby resulting in a loss of potential income from draft or packing.

Artificial insemination (AI) has been used successfully in some countries, notably China, on-station or in the rural areas surrounding larger population centres to reduce inbreeding in yak populations. However, establishing AI facilities and services is not easily done in remote areas (Shijian and Weisheng 1997). In India, it has been recommended that AI be employed where possible using semen from China and that more consideration be given to herd structure, use of better breeding bulls and specific breeding programmes focusing on specific traits (Pal 1997; Pal and Madan 1997). Ultimately, the extent to which AI is used to reduce inbreeding in different countries will depend on the existing circumstances, particularly, the human and financial resources, and infrastructure to support AI. Although embryo transfer has been suggested as a means of improving genetic diversity in yak (Davaa 1997), its use will continue to be limited in the near future due to cost and specialised infrastructure and sanitation requirements.

It maybe worthwhile to mention that inbreeding also poses potential problems in countries where yak rearing is not traditionally carried out. Yak are being raised in Europe, Canada and USA on a very small scale (probably less than a total of 2000 animals) mainly for meat, and to a limited extent as pack animals for trekking, and some fibre production. There are also a few yak herds in Germany and Switzerland. Access to financial resources alone is not enough to ensure that inbreeding does not occur. In Switzerland owners have the money to import semen or embryos, but this is prohibited by law (Daniel Wismer, personal communication). In Canada and USA there are currently 72 registered yak breeders. Bulls are exchanged between herds to prevent any more inbreeding than has already taken place. AI using semen from the registered herds is not widely practised. Government regulations currently prohibit the importation of semen from China and elsewhere (Phil Wykle, personal communication).

Monitoring traits

Herders are probably the single most important factor to be considered when making efforts to reduce inbreeding in yak. As noted by Ning et al. (1997) and Wu (1998), pastoralists'

societies have both the traditional knowledge and skills to improve the production characteristics of their yak and have established procedures for selection of animals. It is widely accepted that this type of information needs to be collected and incorporated into programmes aimed at reducing inbreeding. For a programme to be sustainable, the herder must be fully integrated into the process, understand why information is being collected and how it will be used, and be able to see the tangible benefits to be realised by participating. One possible way to begin this process would be to introduce a simple means of recording information on parentage, management and production and performance traits of animals in the herd (Table 1). Herders and extension workers, in consultation with researchers and livestock advisors, can further develop the card to include other information as necessary. Attributes or traits deemed important by herders can be added to the basic data recorded for each animal. A copy of the card would be kept with the herder and a copy with the recorder. Periodically, the information would be transferred to the responsible institution for data entry, analysis and evaluation.

Use of such a system to monitor breeding activities within and between herds will allow participating farmers to better evaluate animals when making selections for mating. Individual record card would distinguish between those animals having certain desired production and performance traits and those that do not. Because farmers owning these animals are part of a recognised performance recording programme, their animals are likely to be viewed as being more valuable (Schneider et al. 1999). One goal of such a recording programme would be to reduce inbreeding within herds. However, even if inbreeding does occur, there would at least be a record of it. By having access to such information, extension workers, researchers and livestock planners can better identify areas or regions with more acute inbreeding problems and, where possible, take appropriate action. The system could be developed and expanded to include monitoring of animals of different breeds and from different areas, in order to provide a basis for identifying locations for carrying out studies to gather information on genotype–environment interaction (Weiner 1997).

It is recognised that there are numerous obstacles one faces when trying to introduce such a recording system, notably lack of finances, infrastructure and trained personnel. However, these are not insurmountable (Trivedi 1998). Rather, the key factor will be to gain the trust of the herders so that they will actively and fully participate. In this regard, previous contact with herders can be an advantage in introducing such a recording system. For example, herd or farm surveys have been carried out in India (Pal and Madan 1997) and in Tibetan Autonomous Region, P.R. China (Ruijun et al. 1994). Organisational support could be given to herders in different yak-rearing areas to form breeder's associations or groups. Associations such as those, which exist in Xinjiang, China, could be used as a model. Herders and officials have established breeding methods for identifying entire groups of yak, eliminating inferior animals from the breeding pool and establishing core breeding groups (Ning et al. 1997). Sherchand and Karki (1997) proposed group-breeding schemes in Nepal. Building on these and other experiences will facilitate the introduction of such a recording system in new areas and support its development in others.

Table 1. *Yak record card.*

Name of Herder
Breeder's Association (Group)
Location (region, county, district)
Name of Extension Agent

General
Animal identification
 Number
 Sex
 Age
 Breed or type
Acquisition
 Within herd
 Other (purchased, traded, etc.)
 How long in herd
Primary use
 Milk
 Meat
 Draft
 Packing or transport
Breeding/Reproduction
Sire
 Age first used for breeding¹
 Reason for use
 Seasons used
Dam
 Date first bred²
 Sire identification
 Age at first calving¹
 Sex of calf
Production
 Milk
 Lactation length (days)
 Average daily yield (kg)
 Butter (kg)
 Hair (kg)
 Date of removal²
 Reason (sale, death, etc.)
Health
 Vaccinations
 Deworming
 Incidence of diseases
 Injuries
Others
 Phenotypic abnormalities
 Physical abnormalities
 Temperament

1. Months/years. 2. Season/month/year.

Related factors

In addition to production and performance goals, political or economic factors can also have an impact on breeding management. The closing of borders between Tibetan Autonomous Region and Nepal, which severely reduced animal movement, has been attributed to causing inbreeding and negatively affecting yak production (Joshi et al. 1994). Given the recent change in the border situation, more opportunities to introduce new blood lines into Nepal, either by importation of yak males for natural mating or through AI, are likely to become available. Thus, the need to monitor breeding activities and herd structures in areas along the frontier will become increasingly important.

One can expect to and also see a gradual shift away from traditional production systems to more commercially oriented ones as previous income generating opportunities for herders change and new ones develop. In the major trekking areas of Nepal, yak and yak hybrids are increasingly being used for trekking and mountaineering expeditions, thereby transforming the structure of herds in some areas to a much higher percentage of pack animals (Joshi et al. 1994). The continued popularity of these expeditions is likely to result in Nepal and neighbouring countries exploiting such tourist activities to earn more foreign exchange. Under such situations, herders will quickly recognise the potential income to be realised from producing pack animals and modify their breeding practices accordingly.

Closing remarks

While research stations and government farms can play a positive role in developing potentially viable breeding and selection strategies, long-term and sustainable improvements can only be realised at the herder or farm level. The recording system proposed here, albeit simple, can promote the involvement of herders in gathering baseline information, which is currently lacking on herd structures and breeding management. The system is flexible and can be modified as required. Outputs will lead to improved yak production and performance, and contribute to breed sustainability and genetic diversity.

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Resources of yak production in Tibet and reasons for the degeneration of productive performances

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Summary

This paper reports about yak herd structure, growth and development, productive performance in terms of meat, milk, wool and undercoat, and reproduction in Tibetan Autonomous Region. We made recommendations to avoid further degeneration of yak production, particularly, the need to balance the number of yak and forage production, better use of the available natural pasture resources in the cold, high altitude rangelands and to protect the environment from degradation are suggested as being essential for a sustainable yak and pasture production system in the region.

Keywords: Degeneration, natural resources, productive performance, Tibet, yak

Introduction

Yak is the domestic animal species on the Tibetan Plateau. In 1998, there were 3,749,864 head of yak distributed all over Tibet (Tibetan Bureau of Agriculture and Animal Husbandry 1998). Yak have been considered as a very suitable animal to effectively convert the primary production supplied by the cold highland vegetation into various animal products: milk, meat, skin, wool and dung through their intensive growth capacity and fattening potential under situations where the season with adequate green forage is relatively short and at an altitude over 3500 metres above sea level (masl) at which other livestock species rarely adapt (Zhong 1997). In particular, yak live on the unpolluted highland pasture to produce the green, nutritional and relish-specialised products, which are advocated by the modern communities.

Due to its important position in the Tibetan daily life, yak production and its related products are the key industry of Tibetan animal husbandry which plays a key role in providing food, oil and meat to the local nomads in the region. Therefore, further investigation into the yak production resources in Tibet is essential in order to develop a sustainable yak industry.

Materials and methods

Investigation into the topographical distribution, climate, soil, pasture, productive structure and economy of the areas where the three Tibetan yak breeds are found in Tibet was conducted in a study that involved 156 households. Data collected also included herd structures in terms of species composition, sex and age of yak, and reproductive performances.

The body conformations of 225 yak from the three breeds were measured. A total of 40 hair and undercoat samples were collected for further laboratory analyses. Daily milk yield of 109 yak were recorded for 5 days in August and 17 yak were slaughtered for the assessment of carcass parameters.

Results and discussion

Yak population and geographic distribution in Tibet

There were 3,749,864 yak head in 1998, representing 16.69% of the total domestic ruminants in the region (Table 1) and represented by three breeds known to exist in Tibet: Pali, Jiali and Sibü yak.

Table 1. Distribution and number of yak in Tibet.

Prefecture or city	Naqu	Ali	Lhasa	Sigatze	Shannan	Changdu	Linzi	Total
Ruminants	6,657,400	2,295,000	1,677,858	5,573,579	2,194,398	3,446,263	619,395	22,463,860
Yak	1,313,200	122,462	420,722	526,923	245,580	976,104	144,868	3,749,864
Percentage (%)	19.73	5.34	25.07	9.45	11.19	28.32	23.39	16.69

Source: Tibetan Bureau of Agriculture and Animal Husbandry (1998).

Yak herd structure

From the 1997–1998 survey, the species structure in areas where the three yak breeds were dominant were as follows:

Pali yak: yak–sheep and goat–cattle–horse–donkey–mule;

Jiali yak: yak–sheep–goat–horse–pig–yak crosses–chicken;

Sibü yak: yak–goat–sheep–cattle–donkey–horse–chicken–yak crosses–pig–mule.

The herd structure in terms of age and sex is shown in Table 2. For all three breeds, the sex ratio was 1:1 up to 3 years of age. From the age 4 years upward, both sexes matured and joined the breeding groups. Males aged 4–6 years were castrated for meat or draft purpose, if not selected as breeding bulls.

Within the Pali yak, the proportion of females increased from the age of 4 years upwards. The males constituted 13.35% of the herds, females 39.05%, reproductive

females 45.07% and breeding bulls 1.8%. The sex ratio was 1:15.5 among the 5 year-old animals in these herds. These results indicate a sex and age structures scope increase in the population.

Table 2. Herd structure of the three yak breeds.

Families		Percentage in total yak (%)											
Breeds involved	Yak	1 year		2 years		3 years		4 years		>5 years			
		G	E	G	E	G	E	G	E	G	E	G	E
Pali	29 2059	35.8	65.2	7.78	8.8	5.88	5.49	4.23	5.0	3.11	6.02	13.35	39.05
Sibu	39 1081	46	54	7.77	9.12	5	5.14	4.36	3.78	4.75	4.17	25.61	29.87
Jiali	34 20,952	37.2	62.8	7.22	7.74	7.12	8.37	5.74	5.74	5.31	7.0	18.98	29.88

For the Sibu yak, the male percentage was relatively high (25.61%). This was due to the use of bulls as draft animals in the transition zone in which this breed is predominantly found. The reproductive females accounted for 34.04% in the herds while breeding bulls represented only 0.58% of the herd. Sex ratio was 1:26.3 among the 5 year-old animals in these herds.

In the Jiali yak, the proportion of females was 31.88% and that of breeding bulls was 2.82% among the 5 year-olds in the herds. The sex ratio was 1:11.3.

Milk production

Peak milk production in the Tibetan yak is in August (Dou 1990) and there is a significant correlation ($r = 0.993$) between the observed milk yield during this period and the estimated yield during other months (Zhang 1989; Zhong 1997). On this basis, 5-day milk yield of the three breeds were recorded in August and used to estimate the milk yield from May to October in the study. The results showed that the total milk yield was different in the three breeds (Table 3).

Table 3. Estimated total and monthly milk yield of the three yak breeds.

Breeds	Milking method	Total (kg)	Monthly yield (kg)					
			May	June	July	Aug.	Sept.	Oct.
Pali	Full milking	214.80	25.78	34.37	47.26	53.70	36.52	17.18
	Half milking	184.80	22.18	29.57	40.66	46.20	31.42	14.78
	Average	199.80	23.98	31.97	43.96	49.95	33.97	15.98
Jiali	Full milking	192.00	23.04	30.72	42.24	48.00	32.64	15.36
	Half milking	103.20	12.38	16.51	22.70	25.80	17.54	8.26
	Average	147.00	17.71	23.62	32.47	36.90	25.09	11.81
Sibu	Full milking	216.00	25.92	34.56	47.52	54.00	36.72	17.28
	Half milking	143.40	17.21	22.94	31.55	35.85	24.38	11.47
	Average	179.70	21.56	28.75	39.54	44.93	30.55	14.38

Meat production

The measurements of body conformation and body conformation index are shown in Tables 4 and 5. The Jiali yak had the highest body length index which is similar with what is reported for beef cattle breeds. The males also had a higher heart girth index, implying possible higher meat production. Sibü and Pali yak had a higher chest width index with the Pali females also having a higher body length index.

The data in Table 6 shows that the Jiali yak had a higher dressing percentage, net beef percentage and ratio of net beef to carcass weights than the Pali and Sibü yak. Sibü males had a lower beef productive performance but the differences between the females of the three breeds were not significant.

Hair and undercoat yield

Yak hair is harvested in July and August in Tibet. A total of 17 adult males and 9 adult females of the Jiali yak produced 0.69 kg and 0.18 kg on average, respectively. The average undercoat yield of the Jiali yak was 0.6 kg per adult animal. Pali yak produced an average of 0.15–1 kg of hair and 0.2 kg of undercoat. Yak is the only bovine species producing the undercoat with fine fibre, which has a good strengthening length and elasticity, and is now widely used in textile and has a very promising market both locally and internationally. Yak hair is used for making tents, ropes and bags, which are currently popular in Tibet and could be promoted internationally.

Reproductive performance

There was no difference, in both male and female reproduction, among the three yak breeds in Tibet. In general, Pali females come to the first oestrus at 3 years of age with a low conception rate, if serviced but improving with age to best conception at the age of 4.5 years. Sibü females show first oestrus at 2.5 years of age but are served only after 3.5 years of age. All females calve every two years, and these are usually single births as twinning rate is only 1–2%. The calving rates by natural service are 30.77, 48.38 and 45.71% for the Jiali, Pali and Sibü yak, respectively. All males are used for service only after the age of 3.5–4.5 years. However, older bulls tend to have more mating opportunities due to the ranking order in herds. Bulls aged 10 years or older may not be sexually active or could be infertile but they will keep their position in the herds. This lowers the calving rate and increased grazing pressure unnecessarily by having to keep extra unproductive males.

Table 4. Measurements of body conformation of the three yak breeds in Tibet.¹

Breeds	Sex	No.	Head Length	Head width	Height	Length	Chest height	Chest width	Heart girth	Rump width	Height at rump	Cannon bone	Body weight (kg)
Pali	G	2	46.00 ± 2.83	24.25 ± 3.18	112.00 ± 6.63	131.50 ± 13.44	61.5 ± 0.00	32.50 ± 2.83	157.50 ± 2.12	34.50 ± 0.00	112.50 ± 0.00	18.50 ± 2.83	236.64 ± 31.11
	E	21	39.60 ± 3.17	19.14 ± 0.84	110.21 ± 4.26	120.57 ± 9.50	60.55 ± 2.57	32.83 ± 2.55	154.10 ± 4.32	31.28 ± 1.93	105.69 ± 4.22	15.62 ± 0.89	200.85 ± 22.13
Jiali	G	18	48.03 ± 12.24	25.03 ± 3.43	127.47 ± 9.26	151.83 ± 14.00	73.53 ± 6.99	41.22 ± 4.36	186.78 ± 18.12	39.83 ± 3.43	117.47 ± 7.03	20.13 ± 2.25	368.02 ± 90.96
	E	31	40.23 ± 1.65	18.90 ± 0.80	108.18 ± 3.46	120.19 ± 6.19	58.05 ± 6.77	33.63 ± 4.51	147.77 ± 5.99	31.13 ± 1.69	103.31 ± 3.47	14.92 ± 0.83	189.66 ± 20.62
Sibu	G	8	46.25 ± 4.40	20.19 ± 2.03	111.5 ± 2.5	121.75 ± 9.71	59.06 ± 6.26	33.31 ± 3.69	152.13 ± 14.10	32.31 ± 3.03	105.75 ± 6.32	16.28 ± 1.42	204.42 ± 54.69
	E	41	42.78 ± 1.72	17.70 ± 0.85	105.30 ± 4.19	116.80 ± 5.27	57.01 ± 2.91	33.26 ± 2.16	145.85 ± 5.74	29.57 ± 1.68	100.49 ± 3.42	14.96 ± 0.73	172.87 ± 87.00

1. Units of measurement: cm for all except the body weight in kg

Table 5. Body conformation index of the three yak breeds in Tibet (%).

Breeds	Sex	Limb length	Body length	Heart girth	Chest width	Height at rump	Cannon bone
Pali	G	45.06	109.40	139.82	54.22	95.90	14.17
	E	46.54	114.29	131.05	54.94	96.50	15.82
Jiali	G	42.32	115.54	146.53	56.06	92.16	15.79
	E	45.06	111.10	136.60	57.93	95.50	13.77
Sibu	G	45.06	110.92	138.50	58.34	95.43	14.11
	E	41.03	109.19	136.44	56.40	94.84	14.60

Table 6. Beef productive performances of the three yak breeds in Tibet.

Breeds	Sex	No.	Live weight (kg)	Carcass weight (kg)	Net beef (kg)	Dressing percentage (%)	Net beef (%)	Net beef/ carcass (%)	Bone/ beef
Jiali	G	2	314.45	157.89	140.89	50.38	44.97	89.24	1:4.16
	E	3	203.45	103.21	83.54	50.79	41.06	80.94	1:4.25
Pali	G	3	332.74	164.58	137.15	50.84	42.40	83.17	1:4.96
	E	3	221.59	106.58	85.75	48.10	39.08	80.50	1:4.16
Sibu	G	3	254.65	114.13	88.67	44.76	34.82	77.69	1:3.48
	E	3	205.94	101.29	82.62	49.18	39.98	81.55	1:4.43

Evidences for the degeneration of yak production in Tibet

A comparison of the results from this study with previous reports indicates that performance has been decreasing over the years in terms of both beef and milk production among all the three yak breeds in Tibet. For example, the milk yield of the Jiali yak averaged 202.24 kg in 1980 (Dorji 1995b) but dropped to 147.6 kg in the present study. The average dressing percentage in males and females dropped by 15.78 and 5.9% in Sibu yak, 8.4 and 3.2% in Jiali yak, and 10.81 and 10.86% in Pali yak, respectively.

Issues for future actions

1. Cull bulls aged 10 years and older and exchange breeding males among herds and villages. The optimum service age of breeding bulls should be 4 to 10 years. However, most herders have over-age animals, including those up to 15–17 years of age. This was found to be common in Sibu yak herds. Such bulls cause reduction in conception rates. Furthermore, inbreeding, which significantly affects beef production, is common due to a limited number of breeding bulls kept and used for extended periods in the herds by smallholders after the formulation of a livestock tenure policy 20 years ago in Tibet.
2. Optimise species and herd structures. Although the yak is the predominant species in the areas inhabited by the three yak breeds, this study also found that there are many horses (4.76% of the large domestic ruminants) in the Jiali yak producing area. Because the horse is no longer used for transportation since 1990 due to extensive use of motor vehicles, their numbers should be reduced in these herds, as they do not make significant economic contribution to the herders. There were also many goats with low cashmere and meat production in Pali and Sibu yak producing areas. These should also be reduced due to their negative effect on the pasture ecology.

Pali and Sibu yak herders had many over-age females, including those aged 18–22 years in Sibu herds. A high proportion of unconfined yak (up to 5% in some areas) by the local Tibetan religious custom also increases pressure on grazing land. In particular, the male to female ratio of Sibu yak of 1:26.3 is too high compared with the normal 1:15–20.

3. There is strong need to secure winter pasture and to preserve hay and crop by-products for use in the long, cold season. Overgrazing and irrational grazing are common in Tibetan herding system, which reduces the reserved winter pasture area and storage. There is also a severe shortage of supplementary feeds in the cold season. These result into severe degeneration of pasture and subsequent difficulty to attain full recovery of yak body weight loss during and after the long, cold season in Tibet.
4. There is also need to strengthen selection and breeding system to improve the genetic potential of the yak herds in the area. All the three yak breeds identified in Tibet are indigenous to Tibet. However, there has never been a well-planned selection and breeding strategy. This, plus the poor feeding, may be responsible for the degeneration of yak growth and development. In setting up a breeding programme, the indigenous breeding practices and goals of the herders need to be taken into account.
5. The study has also identified a need to improve feeding and management in order to increase individual animal output. The natural herding and management system has been a very effective practice in yak production. However, extraction of increasing amounts of milk as the market demand has been increasing is significantly affecting the growth and development of the newborns and cows as well. In addition, the traditional link between number of heads of livestock and wealth as perceived by local nomads is also negative and inconsistent with increases in individual animal productivity.
6. Encourage more input for pasture protection and reconstruction. There was almost no individual responsibility and investment to protect communal pasture from overgrazing and irrational use after the livestock tenure policy. The pasture tenure policy, which has been adopted in other Provinces bordering Tibet in China, is recommended so that enthusiasm and collective sense of duty by all local herders could be used to ensure responsible pasture management. To ensure sustainable yak production and environmental conservation, the Government also need to provide both financial assistance and policy support for pasture rehabilitation and management.

Special remarks

Increasing human population pressure in the rural area

Average annual birth rate in Tibet has been 23.52% since 1990 (Dorji 1995a). The consequent increase in human population pressure has necessitated keeping more livestock, creating severe shortages of pasture. Family planning should be considered to mitigate this pressure to available resources from the increase in both human and yak populations.

Influence by global climate change

The global climate change is already evidently significantly affecting the microclimate in Tibet in recent years. The increase in temperatures is causing increased evaporation and

decreased humidity. These changes will, in turn, result in reduced milk yield and conception rate of yak in this hot and dry environment.

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Analyses of breeding traits in Maiwa yak

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Summary

The paper presents results of analyses of nine breeding traits in Maiwa yak using principal component and cluster approaches. Results revealed that the nine traits could be divided into three groups: body size traits, milk traits and, hair and horn. The first two groups are the most important for yak production in terms of growth and development and should be considered as the basis for selection and breeding of the Maiwa yak.

Keywords: Cluster analysis, Maiwa yak, principal component analysis

Introduction

Maiwa yak, one of the fine breeds of yak in China, are mainly produced in Hongyuan and Ruoergai Counties of Sichuan Province. In order to improve productive performances (milk and meat), a series of selection and breeding trials and controlled mating have been conducted in recent years. However, the selected traits are mainly quantitative traits. These traits are highly correlated and some desirable ones are negatively correlated with undesirable ones. In this article, nine traits were analysed by two multivariate methods—principal component and cluster analyses so as to determine the relationship amongst the quantitative traits and to provide theoretical basis for breeding work of the Maiwa yak.

Materials and methods

The data analysed in this study were obtained at Longri Stud Farm in Sichuan Province. The nine traits were recorded on 353 healthy female yak. The traits were: body weight (x_1), body height (x_2), body length (x_3), heart girth (x_4), presence or absence of horns (x_5), hair colour (x_6), milk fat ratio (x_7), milk yield (x_8) and hair yield (x_9).

Cluster analysis: Euclidean distance between two traits was used (Tong 1986). The distance, D_{ij} , was calculated as: $D_{ij} = [\sum(X_{ik} - X_{jk})^2]^{1/2}$. The shortest distance method was used for Cluster analysis.

Principal component analysis: After data standardisation, the relevant matrix among variables is $[R]$, where R_{ij} , the elements of the matrix, was calculated as $R_{ij} = \sum X_{ki} X_{kj} / n$, thus forming the formula of characteristics: $Rb = \lambda b$. The characteristic root and the

corresponding characteristic vector were determined by adopting Jacobi method. With $\lambda_1 > \lambda_2 > \dots > \lambda_m$ and the corresponding characteristic vector, the principal components were sequentially determined: $Y_{ij} = b_{11}x_{1i} + b_{12}x_{2i} + \dots + b_{1m}x_{mi}$, as well as the contribution rate, cumulative contribution rate and factor load (Tong 1986).

Results and discussion

Correlation of the traits

From the correlations of the traits (Table 1), body weight was found to have significant positive correlation to heart girth, body length, body height and milk yield, and there was also very significant positive correlation among the three body size traits (height, length and heart girth). There were significant correlations between horn and heart girth, body length and body weight as well.

Table 1. Correlation matrix among the nine traits.

Traits	Body weight	Height	Length	Heart girth	Horn	Colour	Milk fat	Milk yield
Height	0.74**							
Length	0.79**	0.68**						
Heart girth	0.86**	0.77**	0.74**					
Horn	-0.13*	-0.08	-0.12*	-0.15**				
Colour	0.02	0.003	-0.05	-0.02	0.05			
Milk fat	-0.09	0.02	-0.01	0.002	-0.05	0.004		
Milk yield	0.39**	0.17*	0.11	0.25**	0.11	-0.03	-0.31**	
Hair yield	-0.15	-0.08	-0.16*	-0.13	0.01	-0.08	-0.15	0.08

** = very significant; * = significant.

Classification of the traits

Results of clustering of traits based on Euclidean distance indicated that the three body size traits (body height, body length and heart girth) aggregated to a group first, then sequentially aggregated with the body weight, milk yield and milk fat, and finally aggregated with the hair colour and yield. This also reflected the correlations among the traits (Figure 1).

Factor load and index combination

It can be seen from Table 2 that all characteristic roots with principal components analysis from correlation matrix of traits are not very good. Until the fifth principal component, its cumulative contribution rate is just up to over 85%. The factor load of the first five principal components and their index combinations of main traits were further analysed and the results are shown in Table 3.

As is visible from the factor load, the 1st principal component mainly synthesises the body weight, body height, body length and hearth girth and their factor loads are greater: all are above 0.8. These traits mainly reflected size-type information. The second principal component mainly synthesises the milk fat and milk yield, and the factor load is over 0.7. The third and fourth principal components synthesise information about hair colour and horn, and the factor load is over 0.6. The fifth principal component synthesises information about hair yield. These results show that all nine traits can be summarised into body size, milk fat and yield, and hair colour and horn as well as hair yield.

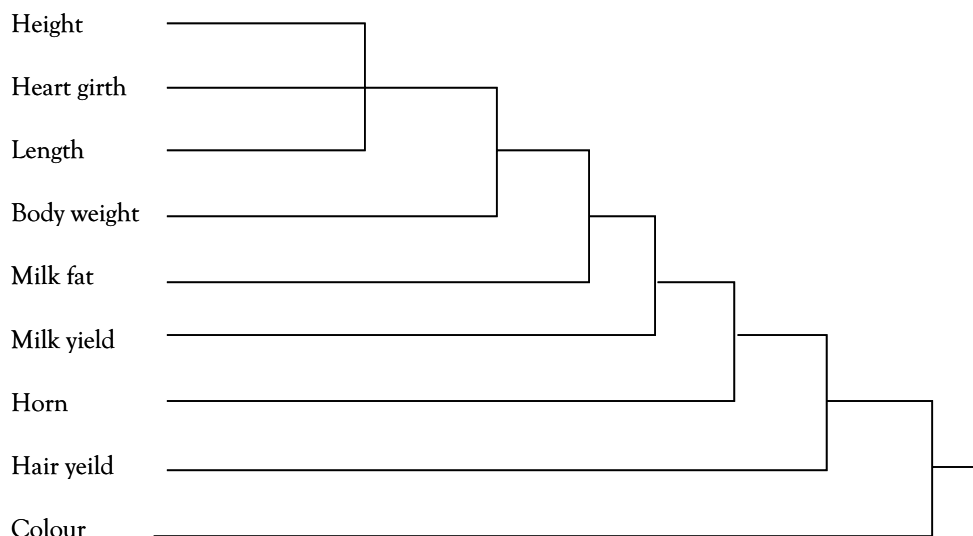


Figure 1. Cluster on the nine traits of Maiwa yak.

Table 2. Characteristic root (λ_i), contribution rate (Λ) and cumulative contribution rate (Λ_i).

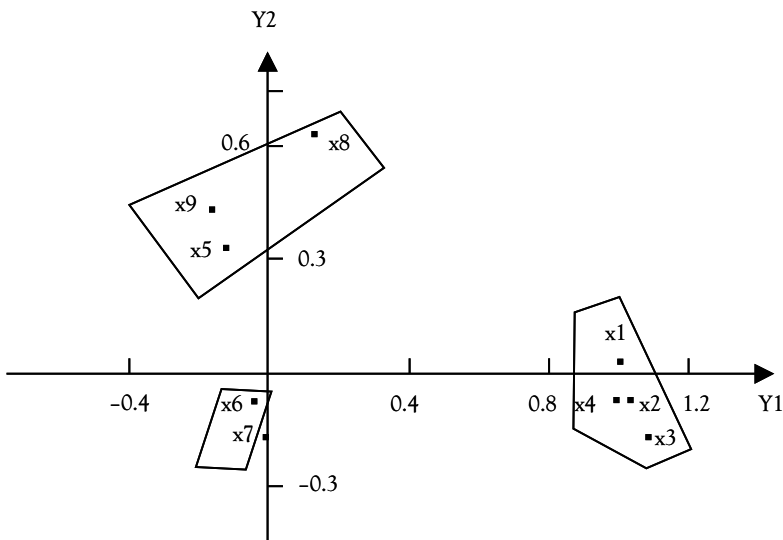
Components	1	2	3	4	5	6	7	8	9
λ_i	3.43	1.42	1.09	0.93	0.84	0.66	0.32	0.21	0.10
Λ (%)	38.09	15.78	12.07	10.33	9.34	7.36	3.51	2.37	1.15
Λ_i (%)	38.09	53.88	65.94	76.27	85.62	92.97	96.49	98.85	100.00

Classification of principal components

Based on factor load (Table 3), taking the first principal component value as abscissa and the second as ordinate, one can draw a plane to co-ordinate point cluster (Figure 2). The result shows that the 1st group of traits included body weight, body height, body length and hearth girth, the 2nd group of traits covered milk fat percent and hair colour, and the 3rd group of traits involved milk yield, horns and hair yield, which confirmed to the abovementioned cluster results.

Table 3. The factor load of the first five principal components.

Traits	1	2	3	4	5
Body weight	0.949	0.074	0.043	-0.019	-0.019
Heart girth	0.927	-0.048	-0.026	0.001	0.076
Length	0.868	-0.131	-0.036	0.055	0.045
Height	0.860	-0.070	-0.006	0.031	0.199
Milk fat	-0.059	-0.740	-0.007	0.279	0.336
Milk yield	0.336	0.708	0.132	0.057	-0.191
Horn	-0.019	-0.099	0.736	-0.621	0.246
Colour	-0.162	0.316	0.569	0.651	0.295
Hair yield	-0.179	0.482	-0.447	-0.187	0.705

**Figure 2.** Two-dimensional distribution for the nine traits of Maiwa yak.

Both clustering and principal components classification for Maiwa yak breeding traits have basically the same results. However, from principal components classification it can be seen that:

1. the closer the distance in various factors, the stronger the positive correlative action. The positive correlative action is gradually reduced in magnitude.
2. the stronger the positive-going and negative-going action of the factor, the farther the factor is away from the second main axis (Y2). The factor without notable positive-going and negative-going action is located at left and right sides near Y2 axis, and the positive-going one is at right side of Y2 axis. All of these show that the information derived by principal components classification is substantial.

It can be seen from the results of principal components analysis that the 1st principal components mainly contain body-size traits, the 2nd principal components mainly milk

traits, and their factor load is higher, which indicate that these traits have greater influences on yak growth and development as well as production. Therefore, special emphasis should be laid on selecting these traits in future Maiwa yak breeding programmes and, at the same time, it shall be further analysed in selection and considered in co-ordination, so as to ensure successful breeding work.

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Some genetic parameters of body weight in yak of the Buryat ecotype

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Summary

Dam–daughter and dam–son regressions were used to estimate heritability of body weight in yak. Heritability estimate of birth weight was 0.27 from both analyses. Estimates among animals aged 3 months and older (up to 24 months) ranged from 0.25 to 0.38, but were higher for measurements at ages of 3, 6, 16 and 18 months which coincided with periods when the environmental conditions are optimal, i.e. summer and early autumn. There were no differences between estimates obtained from dam–daughter and dam–son data sets. Phenotypic correlations of body weight at 18 months (age at economic maturity when animals are born in previous March/April) with weights at younger ages (3 to 16 months) ranged between 0.38 and 0.87. These correlation estimates were relatively higher at 3, 6 and 16 months, and indicated an opportunity to identify selection candidates for 18 month body weight based on the weights measured early in life. Possibilities for genetic improvement of body weight in yak are discussed.

Keywords: Heritability, live weight, phenotypic correlation, yak

Introduction

Body weight is a lifetime index of meat productivity of an animal. Research on the genetic parameters of body weight in yak is of particular interest because inheritance of the trait in the species has not been studied to date. This information is required to facilitate genetic improvement of body weight in yak and their hybrids. This study was undertaken to estimate the heritability of body weight in yak at birth and at subsequent ages from 3 to 24 months. Phenotypic correlations were also estimated between body weight at 18 months and those obtained at earlier ages (3–16 months).

Materials and methods

The study was carried out in the yak herds in East Sayan area where the altitude is 1200 meters above sea level (masl). Each herd had one or two bull (s) for natural mating

(Maturova and Katzina 1990). The maternal influence on body weight in descendants was determined in mother–daughter and mother–son combinations from March and April calving ($n = 138$) in animals ranging in age from birth to 2 years. Body weight in dams was taken at the end of fattening period. Heritability was estimated separately for dam–daughter and dam–son data sets using parent–offspring regression. Phenotypic correlation was estimated by simple correlation coefficients of the raw data.

Results and discussion

Body weights at birth and at 3, 6, 8, 12, 16 and 18 months were all measured at different calendar months of the year. Weights at 3 and 6 (summer) and 16 and 18 (early autumn) months of age were taken in the periods coinciding with optimal environmental conditions. Heritability estimates are presented in Table 1, which also indicates calendar months during which each measurement was taken.

Table 1. Heritability estimates of body weight in yak of different ages.¹

	Age of descendants (month)							
	Birth	3	6	8	12	16	18	24
	Calendar months during which weights were taken							
Animal combinations	3–5	6–8	9	11–12	3–5	7–8	9	3–5
Mother–daughter	0.27	0.33	0.32	0.29	0.28	0.36	0.34	0.25
Mother–son	0.27	0.29	0.34	0.31	0.27	0.32	0.38	0.26

1. Estimates are significant at $P < 0.05$.

Heritability estimates were in the medium range, but tended to be slightly higher in the ‘favourable months’ (summer and early autumn). This tendency for (slightly) higher estimates in favourable months was possibly because the environmental component in the phenotypic variance was higher in more favourable environments than in less favourable conditions. There was no discernibly systematic difference between heritability estimates from mother–daughter and mother–son sets of the data.

Generally, increasing the selection intensity can enhance selection response for low-heritability traits. Katzina (1990) reported that phenotypic selection of female yak for the meat yield before sexual maturation could not make desirable improvement if the intensity in terms of an expected gain of a trait was lower than 30%. However, an increased intensity by 50% in terms of additional increases of average daily milk yield by 35 g, daily weight gain by 150–200 g, and reduction of 30 days for getting 190–200 kg body weight would create better progresses. Due to the low inheritability of body weight in yak, we suggested that information from descendant generations should be referred to plan a better breeding programme. Certainly, the interaction between the genotype and environment should also be considered, especially for the data from the favourable grazing seasons.

Phenotypic correlations of body weight at 18 months of age with weights at earlier ages are summarised in Table 2 for females and males separately. Phenotypic correlations of weight at 18 months old (age at economic maturity when animals are born in March/April

of the previous year) with weights at younger ages (3 to 16 months) ranged between 0.38 and 0.87. For both sexes the correlation estimates were higher at 3, 6 and 16 months of age. Although the magnitude of phenotypic correlations does not reflect the magnitude of corresponding genetic correlations, these results point to a possibility that weights recorded as early as 3 and 6 months of age could be used to make verifications about later (e.g. 18 month) weights. Therefore, evaluation of phenotypes of young animals (3 to 6 months) will help to forecast their productivity in elder age and to differentiate yak dams sooner based on performance of their relatives.

Table 2. Phenotypic correlation estimates of 18 months weight with weights at younger ages.

Groups and number	Correlation of 18 month weight with weights at:					
	Birth	3 months	6 months	8 months	12 months	16 months
Female (86)	0.38±0.10	0.75± 0.09	0.77± 0.08	0.38± 0.10	0.43 ± 0.10	0.79± 0.04
Male (52)	0.38±0.11	0.55± 0.09	0.72± 0.10	0.50± 0.12	0.48± 0.12	0.87± 0.07

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Preliminary results of selection and breeding for improved yak production in Linzhou County, Tibetan Autonomous Region, P.R. China

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Introduction

Linzhou County is the second largest county in the Lhasa City, Tibet. Animal husbandry plays an important role in the total agricultural revenue, accounting for 25% in 1999. The population in the county is about 51,384 people, belonging to 8573 families resident in 102 villages of 10 townships. The total area is 450,866 hectare, of which 12 thousand hectare is arable land and 326,473 hectare natural highland pastures.

The main crops are Tibetan barley, wheat, peas and oilseed with a total annual yield of 50 thousand tonnes. The total livestock is 316 thousand head producing 3384 tonnes of meat and 2549 tonnes of milk in 1999. The yak is one of the main livestock species in the county and was estimated at 75,300 head in 1999, constituting 23.7% of the total large ruminants. The meat and milk production from the yak was 72% and 66%, respectively, of the total output in the county in 1999.

Due to the remoteness, severe environment, and poor social and economic infrastructure, yak production is predominantly under extensive management system with very poor feeding, poor health care, and generally low technical input. One of the consequences of this has been serious inbreeding in the herds which has resulted in the degeneration of yak productivity manifested in smaller body size, lower meat and milk yields and poor resistance to the harsh environmental and disease challenges.

Materials and methods

To restore and improve the yak productivity, the county set up a state-owned yak farm in 1985 based on 3666 hectare fenced natural pastures and 120 hectare artificial pasture with support from both the Tibetan Commission of Science and Technology and the Tibetan Bureau of Agriculture and Animal Husbandry. The aim was to select breeding animals at the farm and then to distribute the superior stock to the local farmers in and out of the county. By introducing the top breeding bulls of the Pali yak in Chigatse and Sibu yak in

Mozhugongka, two crossbreeding schemes were followed: either using Pali yak or Sibuyak bulls on the local yak cows.

Results and discussion

The farm now has 605 breeding animals in the two nucleus herds. The reproductive females constitute 57.2% of the total female herd.

By 1999 the farm had supplied 580 top yak bulls to the Linzhou County itself and other counties in four Prefectures in Tibet. In Linzhou there were 32,260 head of improved yak, which accounted for 42.8% of the total yak population in the county. From live weight records, animals aged 0.5, 1, 3, 6 and 8 years weighed 66, 106, 183, 282 and 344 kg, respectively. These weights are higher than those of local yak of equivalent ages by 56%, 56%, 45%, 88% and 51%, respectively. The milk yield of the improved yak during the July to October period was 205 kg. In contrast, the local yak only produce 152.5 kg of milk in this period. From these results, it is obvious that the selection and breeding at this farm has produced remarkable achievements in terms of yak production in the area.

Possibility of increasing yak number and productive efficiency in Kyrgyzstan

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Summary

Yak produce meat, milk, leather, wool, hair and draft power without need of intensive care and feeding. They graze on the natural pasture year-round. Under proper management and breeding systems, the profitability from yak raising can reach to 80% and even more which is incomparably higher than that from other animal industries. Despite its uniqueness, the total number and live weight of yak in Kyrgyz Republic has been reducing in the last two decades; for example, in 1978 there were 79,300 head, but only 20 thousand head left at the beginning of 2000. However, the natural conditions of Kyrgyz Republic may support 200–250 thousands of yak without damage to other kinds of animals and the natural resources. Therefore, it is necessary to increase the number of yak and improve the productive performances through creating breeding systems under concrete economic conditions.

Analysis of the yak herd structure in regions of Tian-Shan shows that the percentage of yak cows in all regions is less than 33% which essentially constrained the increase of the number. The very low percentage of young breeding females around 2 years old also meant that it is impossible to adjust herd structure in the near future. If, however, the percentage of young yak could be increased, the number of reproductive cows will also go up. However, there are less than 60 farms having 100 reproductive cows in 1999.

Low conception rate occurred in most of yak herds. The bulls give high fertilisation at the age of 3 to 6 years old. An important issue not yet being given due attention is that 60% of the bulls used in herds were over 10 years old. Since there is no exchange of bulls between small herds, the bulls may also be used for services to its daughters, which would result in severe in-breeding.

Low reproductive rate may also happen as a result of unproportional ratio of the bulls to cows. In Kyrgyzstan a ratio of 1:20 is a common practice. A right ratio should be 1 to 12. The age of females used for the first calving in the area is around 18 months, which is too young under the harsh environment. Maturity is achieved for a yak cow around 28–30 months. Means of selection and breeding of yak is made impossible through the degeneration of their live weight, high mortality and the decreased adaptability to the high mountain climate.

One hundred yak bulls were imported into Kyrgyz from 1978 to 1991 as an exchange effort which come to a halt ever since. To avoid the in-breeding in Kyrgyz, 'freshness' of yak blood is urgently needed.

Two breeding herds with 129 and 137 yak cows each were formed in Bakai-Tash farm of Talas area with 34 yak bulls. Breeding programme was also carried out at Aikol farm of Ton area. Four breeding yak cow herds with live weight ranging from 290 to 320 kg were organised which was higher than the average live weight of 250 to 260 kg. Thirty yak bulls were distributed to the Son-Ku farm of Kochkor area. We suggest following issues be considered in the near future, among others:

1. investigating the basic information of selection and breeding programmes
2. encouraging the exchange of yak bulls between herds
3. setting breeding yak cow herds with superior live weight and other important economic traits
4. regulating the herd structure
5. developing a market-oriented yak production system.

Review of the research and development of Bayingolin yak in Xinjiang, P.R. China

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Summary

This paper presents the origin, distribution, productive and reproductive performances, and natural environments of Bayingolin yak, one of the Chinese yak breeds in Bayingolin, Mongolian Autonomous Prefecture, Xinjiang, P.R. China. The brief review of past research and development activities on Bayingolin yak covers genetic selection, crossbreeding, embryo transfer between cattle and yak, wool analysis, fattening trials, disease control, physiological and biochemical measurements etc. The paper identifies problems in yak production in the area and suggests possible ways to develop the yak industry in the next five years.

Keywords: Bayingolin yak, crossbreeding, improvement, origin, productive performance

Introduction

Bayingolin Mongolian Autonomous Prefecture is located in the north-eastern part of Xinjiang Uigur Autonomous Region, P.R. China. With 11 million hectare of grasslands, the Prefecture ranks first among all Prefectures in Xinjiang in terms of grazing area. Out of the total grassland area, useable grassland area is 8.6 million hectare, which accounts for one-sixth of the total useable grasslands in Xinjiang. Some 3 million hectares of alpine pastures are suitable for yak production. There are around 3 million domestic animals in eight counties and one city of the prefecture, out of which 100 thousand are yak. The meat production is 60 thousand tonnes in the Prefecture, and total value of animal production is 340 million RMB Yuan (US\$ 1 = 8.2 Yuan during this study) per year.

Distribution of Bayingolin yak and the natural environment in central yak production area

Bayingolin yak are mainly found in Tianshan Mountain area and Baluntai Mountain area in the north part, and in Arjin-Kunlun Mountain in the north-eastern part of the Prefecture. The

Bayinbluk pasture in Hejing County is the central yak production area, one of the most famous highland plateau pastures in China, where the average altitude is 2500 metres above sea level (masl), annual average temperature is -4.5°C , and the ground is covered with snow in the basin for as long as over half a year. The average temperature in January is -26°C , the minimum temperature in the year is -48.1°C . The average temperature in July is 10.4°C , and the maximum temperature in the year is 28°C . There is no absolute frost-free period throughout the year, and the cold season is over 8 months. The annual rainfall is 468 mm, and annual wind speed is 2.2–3 m/s. The mean fresh grass yield is 1774–3404 kg/ha. Bayinbluk grassland has excellent natural pastures. This area is one of the main animal husbandry bases for Xinjiang Uygur Autonomous Region and about 90% of Bayingolin yak are found here.

Origin of Bayingolin yak and its productive and reproductive performances

Bayingolin yak were introduced from Tibet in the early 1920s. Following long-term selective breeding by local Mongolian herdsmen, the Bayingolin yak were developed as a yak breed with common genetic background, relatively uniform body type and appearance, and good meat production characteristics and adaptability to the harsh local conditions.

The live weight of mature male and female yak is 300–400 kg and 200–300 kg, respectively. The height is 120–130 cm and 105–115 cm for mature male and female, respectively. The annual average milk production is 250–300 kg, and the milk contains 6–8% butterfat. The dressing percentage is 40–50%. Annual wool production is 1–3 kg for mature male yak. Mature steer yak can carry 70–80 kg and walk for 30–40 km in a day.

Male yak usually start breeding at the age of 3 years and 4–6 years is the best breeding age. The breeding ability decreases after the age of 8 years. The age at first breeding for female yak is 3 years. The breeding season is June to November. Average oestrous cycle is 20 days and ranges from 15–25 days. The oestrus persistence period is 32 hours and ranges from 16 to 48 hours, but female yak over 8 years of age show longer oestrus time. On average, the gestation period is 257 days and ranges from 224 to 284 days. The reproductive rate is 77.13% in yak herds and yak calves survival rate is 98.65%.

Research and development activities in Bayingolin yak

Selection within the native local herds

To encourage the yak industry to a steady and healthy development and increase the local yak productive performance to continue providing the range of products for the local communities, we followed the yak development guidance of ‘selection within the breed in the native herds and crossbreeding in the commercial herds’, which was proposed after investigation in the central yak production area. The data on the traits of body weight, main body type measurements, growth rate, meat and milk production, and draft ability showed a

serious degeneration of yak herds over the years. For the genetic improvement purpose, we developed and applied 'Standards of Bayingolin yak'. The genetic background, appearance, live weight, body size, wool and milk production, and reproductive performance of individual breeding yak were assessed and all animals with poor performance were eliminated from the breeding herds.

Crossbreeding with wild and semi-wild yak

We also introduced male yak from Datong Yak Farm in Qinghai to get some new blood in 1981 and 1983. In May 2000, the third batch of 292 semi-wild yak were introduced to the Hejing County from the Datong Yak Farm, of which 235 were females and 57 were males. Some 5000 dosages of the pure wild yak frozen semen were introduced at the same time. All introduced animals were kept in the Ulastaichahan Animal Production Farm for acclimatisation to the new environment. After the adaptability of these semi-wild yak was achieved, a pure reproductive herd had been set up to increase the number for further extension to the local farmers for the crossbreeding programme. Regarding the introduced wild yak frozen semen, skilled technicians have been assigned to carry out artificial insemination of the Bayingolin yak with the aim of increasing the meat traits in the herd.

Crossbreeding with Tianzhu White yak

In 1989, eight breeding bulls of the Tianzhu White yak were introduced from Tianzhu Tibetan Autonomous County of Gansu Province. A significant improvement and economic efficiency were achieved by subsequent crossbreeding in local farmers' herds such as the disease resistance and tolerance to cold and harsh highland conditions (Table 1). All the crossbreds achieved the standard of 'Best Grade' on body weight for Bayingolin yak.

Problems and recommendations

Harsh natural environment in yak production area, simple and old production facilities, and lack of forage and grain supplement in the cold seasons are the main difficulties of yak husbandry in Xinjiang. Furthermore, the old traditional herding method of having the yak grazing in migratory system all year around to follow the water and grass are still practised. This results in small numbers of female animals per herd, low reproductive and survival rate, high mortality rates and low off takes.

Table 1. Performance of F_1 crosses between the Tianzhu White and local black yak.

Items	Male	Female
Birth weight of local black yak calves (kg)	12.8±1.0	12.8±0.9
Birth weight of crossbreds (kg)	17.4±1.7	13.8±1.7
Body weight of adult crossbreds (kg)	367.2	265.0
Wool of 2-year-old yak	2.7	2.0

Based on our analysis, the development of Bayingolin yak should emphasise on the breeding to improve productive performance. Development of the yak industry should result into increased animal productivity and better animal products. This, in turn, should increase farmer's income, and improve the living standards of yak-herding families.

If the programme is implemented successfully, yak numbers are expected to increase to 120 thousand by the year 2005 from 100 thousand at present, female ratio will be up to 60%, reproductive and survival rate to 80%, adult and young animal mortality rate decreased to below 2%, and off take increased to 31.7%. For the quality improvement, the 'Standards of Bayingolin yak' will be enhanced. All adult yak in the herds will at least reach grade 3 or above in next five years. At the same time, a series of comprehensive measures will be taken, including introduction of new genetic material, grazing management, and disease prevention and control. All of these will make the Bayingolin yak attain high levels of performance in terms of body size, body weight, reproduction and overall production.

A study on the improvement of yak reproductive performance by introducing wild yak blood

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Summary

Wild yak semen was used in an experiment to study the possibility of increasing the reproductive performance of domestic yak by both artificial insemination (AI) and controlled natural mating. AI and natural mating raised reproductive and survival rates to 68.1% and 64.4%, respectively. Superior benefits were achieved in the study.

Keywords: Domestic yak, reproduction, wild yak

Introduction

In highland pasture ecological environment, yak reproductive ability is rather poor. There is a need to improve the yak reproductive performance. Through the years from 1992 to 1997, frozen semen from wild yak and semi-wild yak bulls were used by AI and controlled natural mating, respectively, to improve the reproduction in yak herds at Saishitang Farm. This paper summarises the results of the project.

Materials and methods

Study area

Saishitang farm is located at the southern Qinghai Plateau, at an altitude of 3500–4930 metres above sea level (masl). The AI station was set up on natural grassland for autumn transhumance (which is roughly at the altitude of 4000 masl). The pasture of the area is of the alpine meadow type and plant species are mainly sedge and gramineous. There are no distinctive four seasons but only cold and warm seasons can be identified. The climate is typically continental with frequent gusts of wind during the cold period. The annual average temperature is 0.6°C and precipitation about 300 mm. There is no frost-free period in the year. The annual growing period of vegetation is about 120 days. The crop species are mainly barley and rape.

Animals

The yak cows used in study were from individual herders, and were aged between 4.5 to 10 years. Most of them were not pregnant in the previous year and were non-lactating at the time of the study. These yak cows were assigned to different groups and given ear tags. Each animal's code, coat colour, physical description and reproductive performance were recorded. Animals were in above-average nutritional status at this time of the year (July to early September), with improving body condition throughout the breeding period.

Semen and semi-wild yak bulls

Frozen semen pellets of wild yak and semi-wild yak were obtained from the Datong Yak Farm. After being thawed, the sperm vigour in the semen was 0.3–0.4 and each pellet had about 10 million viable sperms. The semi-wild yak bulls were evaluated by bull standards and transported to the study area. They were kept in 10 herder households where they were trained to be used for the controlled natural mating.

Synchronised oestrus technique

All cows in the study were treated with hormones to improve oestrus and conception rate by synchronised oestrus technique. A lot of attention was given to cows, which had missed the first oestrus and needed the second insemination or controlled natural mating. The two hormone reagents were tested and optimised to determine the best doses and injection time and satisfactory results were obtained. The hormone treated cows showed a 55% synchronisation rate which was significantly ($P < 0.01$) higher than that of cows in the control group, and conception rate was as high as 72.73%.

The heat period of the yak cow is comparatively short, with less vaginal mucus and weaker symptoms than that of the bovine. The proper AI time should be at the time when the cow accepts detector bull to mount and the follicle development is at advanced stage as ascertained by rectal palpation. This usually happens before 08:00 hour in the morning or after 19:00 hour in the evening.

All the tested cows in the study (including the control cows) were kept from contact with any bulls from outside. At the end of the mating period, all the tested cows were kept in herder households and had good care, and they kept a state of above-average body condition to help their pregnancies and calving and calf survival.

Results and discussion

Artificial Insemination using frozen semen

From 1992 to 1996, 304 cows were inseminated, 266 were re-examined and 194 were found to be pregnant by AI (72.93%). A total of 181 resulting calves survived, thus the reproductive and survival rate was 68.1% (Table 1).

Table 1. Reproductive and survival rate of artificial insemination (AI) group.

Year	No. of cows	Cows serviced		Pregnant cows	Calving		Survived calves	
		No.	%		No.	%	No.	%
1993	91	33	36.3	25	19	76.0	19	76.0
1994	182	108	59.3	78	61	78.2	61	78.2
1995	175	54	30.9	54	35	64.8	30	55.6
1996	149	20	13.4	20	15	75.0	11	55.0
1997	89	89	100.0	89	64	71.9	60	67.5
Total	686	304	44.3	266	194	72.9	181	68.1

Results in Table 1 show that through a set of combined techniques such as introducing wild yak genetics, synchronised oestrus treatment, AI, improved management and sufficient nutrition supplement, a high reproductive and survival rate can be achieved in yak.

Controlled natural mating

From 1992, 10 semi-wild yak bulls were used to service yak cows in 10 herder households. In the subsequent 5 years, a total of 755 yak cows were involved in the study. Out of these, 616 cows (81.59%) got mated, 500 cows (81.17%) conceived and 486 calves survived to weaning. The overall reproductive and survival rate was 64.4% (Table 2).

From Table 2, it is concluded that when the bulls are chosen properly and the male/female proportion are reasonable, with correct controlled natural mating method, a high reproductive and survival rate could be achieved in highland yak production.

Table 2. Reproductive and survival rate of controlled natural mating group.

Year	No. of cows	Cows mated	No. of newborn	Weaned calves (%)	Reproductive and survival rate	
					No.	%
1993	125	99	80	80.8	80	64.0
1994	135	109	88	80.7	85	63.0
1995	140	121	96	79.3	92	65.7
1996	135	120	98	81.7	95	70.3
1997	220	167	135	82.6	134	62.7
Total	755	616	500	81.2	486	64.4

From this study, we can draw the following conclusions:

1. Through introduction of wild yak genetics, offspring vitality can be greatly improved, as can the reproductive rate.
2. AI requires some basic techniques, in the difficult areas, it is suggested to use the semi-wild yak bulls in the controlled natural mating to improve reproduction in yak cows.
3. Introduction of wild yak is not only good for yak reproductive performance, but is also helpful for the protection of the environment in highland pasture. Through these

technologies it should be possible to improve the welfare of the people through improved yak production.

4. The methods of introducing wild yak genetics in domestic yak production should be combined with other techniques and pre- and post-production services such as advanced management (proper female/male ratios, controlled milking and timely weaning), disease control, pasture management, shelter construction, speeding up of finishing and recycling of herds and marketing to increase profit margins.

Present situation and suggestions of yak improvement in Sichuan Province, P.R. China

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Summary

Live weights of 2.5-year-old male and female crossbreds between Holstein and yak were 310 and 305 kg, respectively. These were 192.2% and 168.6% higher than weights of pure yak. The milk yield of the crossbreds was 1019 kg, which was 4.5 times as much as that of the pure yak. The F_1 of (Holstein \times Yellow cattle) \times yak produced 607.9 kg of milk in the first lactation, which was 2.43 times as much as the pure yak. However, due to the sterility of male hybrids, this heterosis could not be fixed. Furthermore, the continuous upgrading of the hybrids by Holstein was considered undesirable as they are not adapted to the plateau environment. In addition, the conception rate and the survival rate of hybrid calves produced by AI were very low and the cost for producing one hybrid calf was more than 200 RMB Yuan (US\$ 1 = 8.2 Yuan during this study). Based on these results, the following suggestions are made with regard to yak improvement in Sichuan:

1. to undertake within-strain selection of the Jiulong yak and Maiwa yak
2. yak improvement should focus on both meat and milk, but with more weight on the latter in Hongyuan County and surrounding counties;
3. Jiulong yak and Maiwa yak can be used to improve local yak in most areas;
4. Holstein and Simmental semen and Simmental \times Yellow cattle bulls can be used to cross with local yak.

Keywords: Hybridisation, improvement, suggestion, yak

History and present situation of yak improvement

In the north-west Plateau of Sichuan Province, there are 4.07 million head of yak, representing 30% of the total yak population in China. This is the home of the famous Chinese yak, Maiwa and Jiulong. The lactation length is 5 to 6 months with a milk yield of 200 to 205 kg. Yak are slaughtered at about 5 years of age with a carcass weight of only 50 to 80 kg. To improve milk and meat production, farmers cross their yak with the native Yellow

cattle. But the milk and meat production of the hybrids are not much better because the Yellow cattle are not much better. In the 1950's, some Holstein bulls were introduced to the Plateau for use in crossbreeding with yak. The milk and meat production of the hybrids were double that of the pure yak, making the crosses to become very popular with the farmers. However, the Holstein bulls did not adapt to the environment of the Plateau and died in large numbers. In the middle of 1970's, the agricultural department in Sichuan started to use artificial insemination (AI) on yak with frozen Holstein semen as an alternative to natural mating. From 1976 to 1991, more than 40 thousand head of yak were bred with AI and about 10 thousand hybrid calves were born. However, the AI stopped from 1992 to 1998 because of budgetary constraints. In 1999, some counties, including Hongyuan, Aba and Ruo'egai started to use AI again. In addition, the Livestock Improvement Station in Aba Prefecture and other county bureaus of animal husbandry introduced about 45 head of male Simmental \times Yellow cattle and Holstein \times Yellow cattle hybrids for crossing with yak. To date there are about 15 thousand head of female hybrids, including 3800 head of Holstein crossbreds.

Effect of improvement

Since the mid 1970's, a lot of studies have been conducted on crossing involving Holstein, Simmental, Shorthorn, Hereford, Charolais and Holstein \times Yellow F_1 with female yak. All of the hybrids expressed high heterosis on growth and milk traits. The milk yield of the Holstein \times yak F_1 was more than two times that of pure yak. The Simmental or Hereford \times yak F_1 expressed significant hybrid vigour in meat production and the live weight gain increased by 42% to 98% compared with the pure yak.

Growth and development

The bodyweight at birth of male and female Holstein \times yak F_1 were higher than that for pure yak by 73.7 and 76.3%, respectively. Corresponding figures for 6-month weights were 59.2 and 66.9% and for 12-month weights 82.7 and 73.2%, respectively. The weight of 2.5 year old male and female (Holstein \times Yellow cattle) \times yak hybrids were 310 kg and 305 kg which were 196.2% and 168.6%, respectively, higher than that for the pure yak.

Milk performance

A study conducted in Waqie Farm in the Hongyuan County in 1981 showed that Holstein \times yak F_1 produced 5.27 kg of milk/day, on average, from May to August. This was 3.3 times the daily milk production of pure yak. The milk fat produced by the Holstein \times yak F_1 was 127.7% more than that of yak. The lactation length of the hybrids was 285 days with a total lactation milk yield of 1019 kg when the animals were fed with some concentrates in the cold season.

Problems in the yak improvement

The Holstein × yak F₁ is popular amongst farmers because of its adaptability, higher milk and meat production and good overall economic benefits. However, backcrossing to Holsteins compromised adaptability. Most farmers backcrossed F₁ females to yak bulls but the offspring grew more slowly with less meat and milk production compared to the F₁ crosses.

The conception and the survival rates of hybrid calves by AI were very low. From 1976 to 1990, 37,091 head of yak were serviced by AI, but only 7610 calves were born and survived. The reproductive rate was 20.5%. This compares to 53.2% by natural breeding on yak. In addition, the cost for producing one hybrid calf was more than 200 RMB Yuan. The farmers could not afford this. So, the production of hybrids could not be sustained.

Present basic condition on yak improvement

The high enthusiasms of farmers in some areas have been attracted due to the great economic benefits associated with crossbreds; there is much enthusiasm by farmers in some areas, for example, Hongyuan, Ruo'egai and Aba. As a result, the price of a crossbred (F₁) cow (3000 to 4000 RMB Yuan) is 3 to 4 times that of purebred yak cows. Farmers in Maiwa Township of Hongyuan County are even willing to pay for AI service for the crossbreeding.

There is a milk processing plant with capacity for 20 tonnes of fresh milk everyday in Hongyuan County. This is the main outlet for farmers in this and surrounding counties.

The government is paying particular attention to yak production. The projects of Jiulong yak and Maiwa yak selection and breeding are currently being carried out in Jiulong County and Hongyuan County.

Suggestions for yak improvement in Sichuan

The selection in Jiulong yak should focus on growth and meat production while that for the Maiwa yak should be milk production. In Hongyuan and the other surrounding counties, selection should focus on both meat and milk. Jiulong yak and Maiwa yak can be used to improve local yak. The hybridisation between Holstein or Simmental and yak can be done in Hongyuan, Ruo'egai and Aba etc.

The Simmental semen and Simmental × Yellow cattle F₁ bulls can be used to hybridise with yak. Simmental × Yellow cattle hybrids are adaptable to the Plateau conditions. Even though their body size is rather large, their high milk and meat production is very good and farmers find them acceptable.

There are specific considerations for the breeding female yak to be used for hybridisation. Breeding female should be 5 to 8 years old, should have a large body frame and, given the value of the male genotypes used and the offspring expected, should be strong and healthy to ensure the production of a strong calf. The animals should be kept on good grazing with salt supplement as necessary.

Heifer Project International's yak project and some proposals for the improvement of the yak industry in Sichuan Province

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Summary

Yak (*Bos grunniens*) is related to cattle and the two crossbred successfully. The yak is adapted to the cold high altitudes of the Qinghai-Tibetan Plateau. In this inhospitable territory above the tree line on the 'roof of the world', there is no cropping and no frost-free period. The yak provides the main means of livelihood for their keepers in an area that would not be occupied by humans without this animal. The yak produces meat, milk and fibre and is used for transport and draft. Despite the importance of the species, only limited amount of research has been done on it, especially in terms of how to improve its uses. This paper discusses ways to make full use of this unique animal in Sichuan Province, with a focus on activities, which have been undertaken by the Heifer Project International (HPI) in this area.

Keywords: Development, HPI, proposal, Tibetan area, yak industry

HPI's yak project in Sichuan Province

The yak is widespread in the cold high altitude area of the Qinghai-Tibet Plateau and its adjacent mountainous areas. They do not compete for land and grain with people but produce meat, fibre and sometimes are used for transport and draft. It is, therefore, an indispensable production resource for the local Tibetan people. Heifer Project International (HPI) chose the yak (and its crossbred the *dzo*) in this area.

Yak project in Ruergai

The project started in early 1989. HPI gave each recipient household one to three 4-5 year old female yak or one 3-4 year old *dzo*. Each recipient farmer signed a 3-year contract undertaking to repay the loan to HPI within 3 years. HPI used the repayment to buy female yak to continue this 'passing on the gift' protocol. In the last 16 years, HPI has directly supported 357 poor recipients with 501 yak or *dzo* and passed on gifts to 346 needy Tibetan

herdsmen with 413 yak or *dzo*. In addition, since the initiation of the project in 1989, HPI has held 52 terms of technical training courses for 2314 recipient farmers from the area.

In 1991, HPI rented a 333 ha piece of pastoral land in Ruorgai. This piece of land was used as a demonstration farm. A 300 m² yak barn was built and more than 200 female yak were procured from inside or outside the county, to constitute the demonstration herd. The demonstration included such things as optimisation of herd structures, fencing of pastures, rotational grazing, seasonal fattening, silage making and storage, and supplementary feeding, hybrid improvement and protection of ecology and environment. A total of 360 improved hybrids were produced through insemination of the yak with frozen semen or natural mating. These were distributed or passed on as gifts to farmers as described above.

Yak project in Songpan

Songpan yak project started in 1996. HPI provided a 3-year loan of 2000–4000 RMB Yuan (US\$ 1 = 8.2 Yuan during this study) to each recipient. The repayment in the first year would be 20%, the second year 30%, and the remaining 50% to be paid off in the third year. The recipients used the loans to buy female yak certified by local technicians as being of good quality. In the last 4 years, HPI has provided 120 thousand Yuan to 25 needy Tibetan or Hui herdsmen to purchase a total of 112 yak. All the recipients, according to the contract, repaid the loans at 6% interest. Now another 14 new recipients have acquired 108 gift animals (including 43 yak, 35 goats and 30 sheep) passed on by the initial loan recipients.

The project now has emphasis on natural resource management and encourages participating farmers (recipients) to keep lesser number of animals but of high quality. Only the best female yak are procured to join herds of participating farmers. The farmers are also encouraged to use organic manure to fertilise the crop and pasture, and to preserve as much animal feed as possible for use during the winter. The project also helps farmers with other aspects of farm management and assists with identification of market outlets, e.g. through tourism sites and hotels where the fresh milk sells 3–4 Yuan per litre. These initiatives have significantly improved the incomes of recipient farmers. Incomes have increased by an average of 800 Yuan, but some as high as 2000 Yuan per household.

Yak project in Rangtang

The Rangtang yak project started in 1996. HPI provided each recipient with 2 yak. According to the contract, each recipient had to repay a female yak and a male calf to a local project partner. The partner would fatten the young yak and sell it and buy a young female yak as a gift to be passed on to a new recipient. In last 2 years, the project has directly provided 128 yak to 64 households of Tibetans. According to available statistics, the gift animals increased incomes in these households by 480 Yuan per year.

To improve the understanding by the recipients of HPI and its operations, project information has been published in Chinese and Tibetan languages. These include information on ‘passing on the gift’ contract and technical information related to animal

management. To pride and be self-confident, a board stating 'HPI project recipient' is hang up on the door of the participated house and the local Buddhist monks are invited to visit such farmers and to assist in the supervision of the project.

HPI's role in promoting yak research and development

Heifer Project International has actively supported and participated in the 1st, 2nd and 3rd International Congresses on Yak. Heifer Project International China Office co-operated with the former chief editor of 'China Yak Journal' and 'Sichuan Yak Development Institute' to set up a 'China Yak Science and Technology Database'. More than 300 abstracts indexed from the journal are included into the database in both Chinese and English. Furthermore, this information has been made available for yak researchers and scholars through the internet (<http://www.hpichina.org/>).

Proposals to the development of Sichuan yak industry

It is estimated that there are slightly more than 4 million head of yak in Sichuan Province, mainly distributed in the north-west plateau and mountainous areas of the province. This represents 30% of the total yak population in the country and places the province only second to Qinghai Province. Sichuan has several yak breeds, including the Maiwa and Jiulong. The province has more than 20 years experience in the use of artificial insemination as a means of improving yak through hybridisation with frozen semen of cattle. Because yak production is 'organic', with no chemical inputs in form of animal feed additives, veterinary drugs etc. yak products have a huge market potential.

There are also some problems, which need urgent attention if the yak industry is to flourish:

1. There is very little attention currently being given to the genetic improvement of the yak.
2. Due to the small herd sizes, inbreeding is a problem in most herds. This is considered to be responsible for falling production levels in many herds.
3. Overstocking is leading to environmental deterioration, which, in turn, will affect the overall production of the system.
4. Yak products are not well developed and the traditional ones are not competitive. There is need to further develop these products and to adopt packaging and brand-naming to facilitate targeted marketing.

In view of the above problems, some proposals are presented below:

Carry out a general development plan for yak industry

A plan for the overall development of the yak industry should be initiated. Such a plan should address all components of the industry and measures, which need to be taken in the province to improve each component, along the lines suggested above.

Further stepping up research co-operation in yak

Strengthening the overall yak research in the country geared towards addressing problems affecting the industry is considered as a key requirement if the industry is to develop. The research should include aspects of technology development for the production of the yak and processing of products, and genetic improvement. The HPI China Office is already involved in supporting yak research. Additional measures are needed to consolidate and co-ordinate these efforts and those of all research organisations in the country

Yak selection and improvement

More efforts should be directed at selection and improvement of Maiwa and Jiulong yak. In addition, different systems of crossing and hybridisation with cattle should be studied. It is considered that when *dzo* represents only 25% of the total yak population, or the female *dzo* population is 30% of all the females in the overall population, the overall reproduction is not compromised. Moreover, the ratio of males and females in a herd should be maintained at 1:15–20, and not current 1:25–30 in most herds.

Improving yak husbandry

Measures should be taken to further improve the management of pastures. Fees for use of pastures is suggested as one intervention. It is necessary to fence the pastures to provide better management. Grassland and wetland should be protected to improve the overall health of the yak production system. Settlement of herdsmen, intensification of grazing and stall-feeding, commercialisation of farm production and popularisation of technologies such as seasonal fattening, supplementary feeding skills and culling old, weak and non-productive yak etc. are all important interventions that should be incorporated into the overall yak husbandry.

Speeding up the development of yak resources

It is suggested that the current breeding areas of the Maiwa and Jiulong yak be targeted for development. Specifically, the western part of the country should be used for this purpose. Policies should be formulated that aimed at promoting yak products to become the choice at home and abroad and among tourists, as healthy and 'green' foods.

In conclusion, the yak is the window of economic development for the large number of people who keep it. There is an opportunity to make this happen and to substantially improve the livelihoods of the yak keepers by developing the animal and its production system.

Yak production and strategy for its further development in Naqu Prefecture of Tibet, P.R. China

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The yak, termed the 'boat of the plateau', has a unique adaptability to the high and cold environment of its habitat. The Tibetans also called it 'Nuo' (or Treasure). There is a very strong relationship between the yak and the Tibetan people living on the Qinghai-Tibetan Plateau. The Tibetans eat yak meat, drink yak milk, use yak dung as fuel for cooking and heating, wear clothes made from yak wool and undercoat, live in tents made from yak hair, ride yak and transport goods with yak. Yak also has a significant influence on the Tibetan religion. Developing the yak can make an important contribution to the livelihoods of the people of Tibet and the overall economy.

Background of the Naqu Prefecture

Naqu is located in northern Tibet, between longitudes 84°N and 95°N and latitudes 30°E and 36°40'E. The total area of the prefecture is about 400 thousand km² and the lowest lying area is at an altitude of over 4500 metres above sea level (masl). The climate is extremely dry, cold and windy. Annual average temperatures in most counties are lower than 0°C. The plant growing period is only 100 days in June, July and August. There is no absolute frost-free period in the prefecture. The rainy season is also in June, July and August when the temperatures are a little bit warm. The annual rainfall is 350 mm.

There are 11 counties in the Prefecture. In 1999, the agricultural population of the prefecture was estimated at 326,600 people owning some 6.9 million head of yak, horses, sheep and goats on a total of 34 million hectare of natural pasture. Income from animal husbandry accounts for 80% of the GDP of the prefecture.

Yak production in Naqu

The prefecture is vast, has low animal and human population density and is diverse in terms of agro-ecozones, pasture types, livestock production systems and economic activities. In this paper we have, for convenience, divided the prefecture into three areas:

1. Eastern area, consisting of four counties of Biru, Suoxian, Baqin and Jiali,
2. Central area, encompassing three counties of Naqu, Anduo and Nierong, and

3. Western area, covering four counties of Bange, Shenza, Nyima and Shuanghu.

Generally, yak husbandry in Naqu is poor.

From Table 1 it can be seen that yak numbers decline with increase in altitude and decrease in annual rainfall from east to west in the prefecture. Male yak reach sexual maturity at 3 years of age and are used for mating from about 3.5 years to 9 years of age. Female yak are bred for the first time at 3 years of age and calve every other year, achieving a total of 4 to 6 calvings over productive life of 8 to 10 years. The sex ratio is 1 male to 20 females and the reproductive rate is about 55%, with a higher rate in the eastern part (Table 2). Because of the better ecological conditions and pastures in the eastern area of the prefecture, yak in this area have higher productive performance (except the production of undercoat) compared with those in western area (Table 3).

Table 1. *Climate and yak distribution in the prefecture (1999).*

Location	Livestock ($\times 10^3$ heads)	Yak ($\times 10^3$ heads)	Altitude (masl)	Rainfall (mm)	Temperature ($^{\circ}\text{C}$)
East	1250	541.5	4300	600	1.5
Central	2482.2	608.6	4600	410	-2.0
West	3179	305.7	4700	250	-3.0
Total	6911.3	1455.8	4500	350	-1.9

Table 2. *Reproductive performances of yak in Naqu (1999).*

Location	Reproductive females		Calves survived ($\times 10^3$)	Reproductive rate (%)	Marketing rate (%)
	Number ($\times 10^3$)	Percentage (%)			
East	185	34.16	127.7	69.03	12.71
Central	159.9	26.27	81.2	50.78	12.38
West	104.2	34.09	46.8	44.91	9.76
Total	449.1	30.85	255.7	56.94	11.92

Table 3. *Average productive performances of yak in Naqu (1999).*

Location	Beef (kg)	Milk (kg)	Undercoat (kg)
East	101.94	136.51	0.41
Central	102.04	74.51	0.54
West	99.09	41.79	0.73
Total	101.46	88.36	0.53

Traditionally, yak are herded on natural pasture for about 10 hours daily year round. They are not kept under shelter, nor are they given supplementary feeds, even in cold seasons. Breeding bulls are grazed far from the yak herds and herders' houses in the non-breeding season. They only come down to the herds in the breeding season during which they are herded together with the cows. The calving season is from April to July. In practice, cows are milked from the second month after parturition. To control suckling, calves are separated from cows during the daytime. Thus, suckling is only during the night

following evening milking. In recent years, the pasture has been degenerating and biomass production has been declining thus adversely affecting the nutrition of the animals. Yak have inadequate nutrition for up to 8 months in a year. This is responsible for the poor body condition of breeding animals, resulting into lower reproductive and survival rates, smaller body size, and reduced overall productivity. Data from an investigation conducted to examine recent trends show that meat, milk and undercoat yields have decreased by 4.17%, 17.87% and 47%, respectively, over the last ten years (Table 4).

Table 4. Comparison of yak productivity in 1991 and 1999 in Naqu.

Year	Reproductive females (%)	Reproductive rate (%)	Individual beef yield (kg)	Individual milk yield (kg)	Individual undercoat yield (kg)
1991	31.79	46.58	105.88	107.58	1.00
1999	44.91	56.94	101.46	88.36	0.53
Change (%)	+41.27	+22.24	-4.17	-17.87	-47

Measures to improve the yak husbandry in Naqu

The following measures are suggested as means to improve yak husbandry in Naqu:

1. Establish a performance recording system including pedigree related breeding programmes which can be implemented on a sound basis.
2. Determine optimal marketing and culling ages: The breeding bulls must be castrated and packing animals must be culled before they attain an age of 8 years; the breeding females and draft animals should be culled before they are 10 years old.
3. Adjust the herd structure: An optimum herd structure is 65% females, 12.3% breeding bulls and 22.7% castrated males. This should yield a sex ratio for all breeding animals of 1 male to 15 females. The age structure should also be considered.
4. Encourage the exchange of breeding bulls between herds in different villages to avoid inbreeding.
5. Set up fenced reserve pastures to provide feeds in the winter and spring seasons: 2 mu (15 mu equals 1 hectare) fenced natural pastures and 0.2 mu artificial pasture per animal are recommended.
6. Build shelters for pregnant cows and young animals for use particularly during the cold seasons.
7. Improve veterinary and disease control programmes using both traditional and modern approaches and medicines.
8. Set up small demonstration programmes to enhance animal and pasture management, including such elements as artificial insemination and skills for setting up artificial (improved) pastures. The aim of such programmes should be to show local farmers what the benefits of these interventions are so that they can have the interest to try themselves on their herds.

Efficient production of transgenic bovine/cat by microinjection and cloning technology of early embryos

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Summary

The present results suggested the feasibility of enhanced green fluorescent protein (EGFP) gene for non-invasive selection of transgenic bovine embryos at the pre-implantation stage by using the fluorescent microscope and linking the marker gene contacted with a desired gene. However, these injected embryos showed impaired development and high rate of the mosaic expression. Therefore, we conducted a trial to transfer the EGFP gene fragment into the bovine or cat foetus fibroblasts using polybrene for expressing bright green fluorescence in the whole inner cell mass. EGFP has a great advantage as a marker because the transgenic cells or organ can be observed at any time in their viable and intact state and it can be easily connected with pharmaceutical protein *in vitro*. Additional advantages of nuclear transfer combined with transgenesis become obvious when it is compared with microinjection techniques. In the future, we can produce the pharmaceutical proteins from cow or cat using nuclear transfer combining with the EGFP gene.

Keywords: Clone, embryo, gene expression, microinjection, transgenic animal

Introduction

Transgenic livestock have been developed for a variety of purposes, including improvement of food products or disease resistance, production of valuable therapeutic products in milk, and as models of human diseases (Hennighausen 1990; Janne et al. 1992; Colman 1996; Echelard 1996; Young et al. 1997; Ziomek 1998). However, the cost of transferring microinjected embryos to recipients that do not generate transgenic offspring is a major constraint to this approach. Therefore, for the production of large transgenic animals such as cattle, detection of the transgene at the pre-implantation stage would be desirable if considering the long gestation period and limited number of offspring. In bovine studies, although several non-invasive methods using firefly luciferase (Menck et al. 1997; Murakami et al. 1998a; Nakamura et al. 1998) or neomycin resistance gene (Bondioli and Wall 1996) as markers have been reported for selection of the transgenic embryos, the former method requires a step for loading the substrate (luciferin) inside the cells which is

known to be toxic, whereas the latter requires the presence of neomycin in the culture medium.

In the last few years, green fluorescent protein (GFP), a protein of 238 amino acids found in jellyfish, *Aequorea victoria*, has been applied for various objectives as a useful marker for monitoring gene expression *in situ* (Chalfie et al. 1994). GFP absorbs blue light and emits green fluorescence without any need for exogenous substrates or cofactors, and this characteristic is of great advantage for GFP as a marker. Since no preliminary steps are required for the detection of GFP, cells or organs can be observed at any time in their viable and intact form by simple use of a fluorescent microscope. Therefore, the present study was conducted as a preliminary experiment aimed at evaluating the applicability of this convenient marker for selection *in vitro* of transgenic bovine/cat embryos. The fluorescence by pre-implantation expression in the bovine/cat embryos was observed after pronuclear microinjection or cloning with an enhanced GFP (EGFP; S65T; +F64L) gene construct (Okabe et al. 1997).

Materials and methods

Experiment 1

The methods used for *in vitro* maturation, *in vitro* fertilisation (IVF), and subsequent cultures in the experiment were modifications described by Boediono et al. (1994). Briefly, cumulus-oocyte complexes (COCs) were aspirated from the follicles (2–7 mm in diameter) of cow ovaries collected at a local abattoir and cultured in maturation medium (25 mM Hepes TCM-199) with Eagle's salts (Gibco, Grand Island, NY) supplemented with 5% superovulated cow serum (SCS), 0.01 mg/mL follicle stimulating hormone (FSH, Denka, Kawasaki, Japan), 20 mM taurine (Wako, Osaka, Japan), and 50 mg/mL gentamicin (Sigma, St. Louis, MO) at 38.5°C under 5% CO₂ in air. After 20–22 hours of culture, the COCs were fertilised *in vitro* with frozen-thawed sperm for 5 hours in Brackett and Oliphant medium (Brackett and Oliphant 1975) containing 2.5 mM caffeine (Sigma), 3 mg/mL bovine serum albumin (BSA, fraction V; Sigma), 20 mg/mL heparin (Shimizu Pharmaceuticals, Japan) and 20 mM taurine, and then cultured *in vitro* in TCM-199 medium supplemented with 5% SCS, 5 mg/mL insulin (Sigma), 20 mM taurine, and 50 µg/mL gentamicin (Sigma, St. Louis, MO) at 38.5°C under 5% CO₂ in air.

After 17 hours of IVF, these presumptive zygotes were incubated with 300 IU/mL hyaluronidase (Sigma) for 20 minutes, and their adherent cumulus cells were removed by repeated pipetting. The denuded zygotes were centrifuged at 16,000 g for 20 minutes in the presence of 5 µg/mL cytochalasin B (Sigma) to visualise the pronuclei (Fahrudin et al. 2000), and then transferred to a 100 µL drop of Dulbecco's phosphate buffer saline without Ca²⁺ and Mg²⁺ [DPBS (-); Gibco] supplemented with 3 mg/mL BSA, 5 µg/mL cytochalasin B, and 50 µg/mL gentamicin. After transfer, the pronuclei of the zygotes were microinjected with approximately 2 µL of the buffer solution (10 mM Tris-HCL, 0.2 mM EDTA, pH 7.5) containing 1.5 µg/mL EGFP cDNA fragment under control of the chicken

beta-actin promoter and cytomegalovirus enhancer (Okabe et al. 1997) using an injection capillary (0.5 mm in diameter) attached to the micromanipulator (Leitz, Wetzlar, Germany). These injected zygotes were cultured *in vitro* for an additional 8 days (until day 9; IVF = day 0) to examine their developmental competence and fluorescent expression.

The green-light emission by the injected embryos was detected under a fluorescent microscope with DM 505 filters (EX 450–490 and BA 520, Nikon, Tokyo, Japan). The developmental stage of the fluorescent embryos was recorded on every second day after injection until day 9.

Experiment 2

The application of nuclear technology using blastomeres of early bovine embryos has been reported (Prather et al. 1987; Fahrudin et al. 2000). The donor nuclei were prepared from the 8-cell stage embryos, which were observed for fluorescent expression.

The recipient cytoplasts were prepared from *in vitro* matured oocytes, which were enucleated at 20–22 hours after the beginning of *in vitro* maturation. Pushing out the first polar body and a small amount of cytoplasm after cutting the zona pellucida with a sharp glass needle did the enucleation process. The successful enucleation was confirmed by culturing the oocytes in the medium containing Hoechst 33342 (2 μ /mL) for 20 minutes, and subsequently exposing to ultraviolet light for a few seconds. All manipulations were done in 20 μ L drops of phosphate buffer saline (PBS) supplemented with 5 μ g/mL cytochalasin B and 0.3% BSA covered by mineral oil.

The embryos were reconstructed by fusing donor cells and presumptive metaphase cytoplasts, the transfer and fusion were accomplished immediately after the enucleation of the metaphase plate of the recipient oocytes.

The fusion was initiated by a single DC pulse of 1 kv/cm for 50 μ sec (delivered by BTX 2001, San Diego, CA) in Zimmerman medium. The fused couple were then perthenogenetically activated by exposing into culture medium (CR 1aa supplemented with 3% BSA and 5% foetal calf serum (FCS)) containing calcium ionophore (10 μ g/mL) for 5 minutes followed by culturing in the medium containing cycloheximide (10 μ g/mL) for 5 hours. After the activation, five to ten reconstructed embryos were cultured in 100 μ L drop of culture medium covered by mineral oil at 38.5°C in humidified chamber with 5% CO₂ in air for 3 days. The developmental stage of the fluorescent embryos was recorded on every second day after fusion.

Experiment 3

The methods used for nuclear technology with foetus cell lines (Takada et al. 1997; Wilmut et al. 1997; Cibelli et al. 1998; Stice et al. 1998) and subsequent EGFP gene transfers in this experiment were modifications of previous reports (Okabe et al. 1997; Murakami et al. 1999).

The donor nuclei (somatic cells) were prepared from bovine and cat foetuses cell lines, which were derived from frozen-thawed foetuses that had been frozen at -20° for about three months. Seven to twelve passages of the cell lines were used as donor nuclei in this study.

We conducted the transfer of the EGFP gene fragment into the bovine or cat foetus fibroblasts using polybrene or electroporation as follows:

1. Culture the cells with 100 ng contents of 1 μ g EGFP cDNA + rhAT (releasing solidification of blood) and 10 mg/mL polybrene in Dulbecco's Modified Eagle's (DME) medium containing 10% FCS for 6 hours;
2. Treat the cells with the medium containing 30% DMSO for 4 minutes;
3. Wash the cells twice and culture for 2–7 days;
4. Observe the green cells under a fluorescent microscope;
5. Select the green cells using a micromanipulator, and transfer them to the other culture dish;
6. After several weeks of culture, colonies of the green cells might be formed;
7. Use as donors for nuclear transfer to bovine or cat enucleated oocytes.

The cells were in DME medium supplemented with 0.5% serum for 4–5 days before being used as donor nuclei. The cloning process and observation of fluorescent expression of embryos were done in the same way as experiments 1 and 2. The developmental stage of the fluorescent embryos was recorded on every second day after injection until day 9. However, the numbers of fluorescent embryos that were observed to include non-fluorescent blastomeres were recorded as the criteria of mosaic expression, regardless of the brightness of light-expression by the embryos.

The rate of development to blastocysts and expanded/hatched blastocysts was compared between the gene-transfer and non-treatment groups, and the rate of fluorescent expression was compared between the whole and mosaic groups using the Chi-Square (χ^2) test.

Results and discussion

In the first experiment, a total of 310 zygotes were microinjected with the EGFP gene construct into the pronuclei. As the first step, the developmental competence *in vitro* of the gene-injected embryos was examined, and the results were summarised. Forty six (14.8%) zygotes degenerated within 24 hours after injection. The cleavage rate for the injection group was lower than that of the non-treatment group. However, statistical comparison between the two groups was not made because the oocytes in the non-treatment group had not been selected for the presence of pronuclei. The rate of development to blastocysts was calculated for the cleaved embryos in order to facilitate the comparison between the injection and non-treatment groups. The rate of development to blastocysts in the injection group was significantly lower ($P < 0.01$) than that of the non-treatment group. Among these blastocysts, the rate of development to expanded/hatched blastocysts was lower ($P < 0.05$) in the injection group than the non-treatment group, 56.8% (25/44) and 73.3% (121/165), respectively.

After gene-injection, the fluorescent expression was observed in a total of 37 (11.9%) embryos. However, although the fluorescent embryos at the blastocyst stage were detected in 2.9% of the injected embryos, six out of nine fluorescent embryos (66.7%) showed mosaic expression in their inner cell mass and trophectoderm. Furthermore, the rate of fluorescent embryos that showed mosaic expression after injection was significantly higher ($P < 0.05$) than the embryos of whole expression (8.4% and 3.5%, respectively).

The developmental competence of bovine zygotes decreased after pronuclear microinjection with the EGFP gene. The centrifugation treatment for the polarisation of intracellular lipids, as performed herein, has been shown to maintain the normal developmental capacity *in vitro* of bovine zygotes in our previous experiment (Murakami et al. 1998b). It has been demonstrated that pronuclear microinjection with either water or buffer decreased bovine embryonic development significantly, and inclusion of DNA in the injection buffer decreased the development even more drastically (Peura et al. 1995). Therefore, the developmental restriction of zygotes that was found in this experiment was considered attributable to the treatment due to mechanical damage resulting from embryo manipulation; influence of the microinjected DNA itself could not be determined. In addition, the frequent observation of the embryos under the excitation light might have detrimental effect on their developments.

Previous studies have shown that the expression of EGFP was detected in preimplantation bovine embryos following pronuclear microinjection with the modified GFP (S65T) gene constructs (Chan et al. 1997; Takada et al. 1997). However, it has been indicated that some GFP-positive morulae became weakly positive or almost negative at the blastocyst stage (Takada et al. 1997). In the present study, such a loss in fluorescent expression was not detected in the light-emitting embryos during the observation carried out after injection of the EGFP (S65T + F64L) gene. On the contrary, some non-fluorescent morulae were observed to emit green-light when they developed to the blastocyst stage, 0.6% (2/31). We could not clarify the cause of the difference in fluorescent expression by the embryos. However, in the study of EGFP transgenic mouse (Okabe et al. 1997), humanised modification of the codon usage in the EGFP sequence was assumed to be responsible for the increased efficiency of their fluorescent expression.

The fluorescence was expressed by the injected embryos at various intensities throughout their development up to blastocyst stage. However, only 1.0% of the injected embryos developed to blastocysts that emitted green-light in their whole blastomeres. Moreover, the majority of the fluorescent embryos showed mosaic expression, 70.3% (26/37). It has been indicated that the mosaic was detectable commonly in approximately half of the fluorescent embryos when the EGFP gene construct used herein was injected into mouse zygotes (M. Okabe, personal communication). Although the exact reason for this phenomenon is unknown, Lewis-Williams et al. (1996) has demonstrated that the incidence of transgenic mosaicism in mouse embryos increased significantly with time after microinjection of a target DNA, using fluorescence *in situ* hybridisation (FISH) analysis. They indicated that most integration events seem to occur after the first cleavage, generating a majority of mosaics among the transgenic offspring. It has also been revealed that delayed integration of microinjected DNA into the embryo genome often results in mosaic founder animals (Schnicke et al. 1997).

In experiment 2, the rate of survival and fluorescent expression of the reconstructed embryos were 69.45 (25/36) and 52% (13/25), respectively. These results indicate that the rate of expression of EGFP gene with the nuclear transfer embryos is higher than that of microinjected embryos. In experiment 3, the results were almost the same as those of experiment 2. EGFP gene will be linked with any pharmaceutical protein during culture with fibroblast cells using polybrene or electroporation procedure. What genes should be added or removed? One gene of interest is the rhAT gene, which is a factor of releasing solidification of blood for human.

Additional advantages of nuclear transfer combined with transgenesis become obvious when it is compared with microinjection transgenesis. One advantage is the time and expense saved with nuclear transfer approach. With nuclear transfer all of the initial offspring are transgenic because the gene of interest is inserted into the fibroblast cells prior to making the nuclear transfer embryos. Then only nuclei from transgenic cell lines are used in the process. Using nuclei from lines of cells in which the sex is known, the sex of the transgenic offspring can be predetermined (in this case as female). This alone saves two years or several months of development time by eliminating one generation of cattle or cat, respectively. Since these are all genetically identical females, testing for expression and herd expansion can be performed rapidly.

In the present study, we used the cat for gene transfer by cloning technology. This technology is very efficient because the gestation period of cat is only 60 days. Therefore, the isolation of the efficiency protein from milk should lead to a safer and more cost-effective product.

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Report on experiment of artificial insemination by frozen yak semen in an area with altitude of 4500 masl

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Summary

Naqu is located in northern Tibet with topography of high hills averaging 4500 metres above sea level (masl), characterised by sub-cold and arid highland climate with no summer season at all. The annual frostless period is about 120 days. Yak production has been the main income source supporting the Tibetan nomads living in the region. The yak population in Naqu was estimated at 1,455,800 head in 1999, the reproductive females constituting about 45% and the reproductive and survival rate was 56.94%. Due to the non-conception of over 30% of the reproductive females, the yak reproduction and productivity has deteriorated over the years. For example, the live weight of yak in the area was in the range 500–700 kg in 1950's but dropped to 200–300 kg in 1999. To improve the yak reproduction and introduce new yak genes into the region, artificial insemination (AI) has been used on trial base on the high alpine pasture.

The frozen semen was taken from the Daxun Yak Frozen Semen Station. The reproductive females were assembled in the Naqu Farm where the yak were in normal body condition, small body size, black colour, and aged from 5 to 13 years. The bulls were separated from the females during breeding season from August to September to allow the exclusive use of AI. Thawed frozen semen with a live sperm rate of 0.4–0.5 was used. A total of 18 females were involved in the trial. Only 17 of them conceived, representing a conception rate of over 94%. This is almost same with the conception rate by AI in the lower altitude areas (4200 masl). From this preliminary experiment, the live sperm rate of thawed semen, temperature in the breeding season and age of the females are thought to be the key factors affecting the conception rate. A large-scale trial is recommended to verify these results for use by the extension service.

Experimental results of oestrus synchronisation in yak

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Summary

Fifty-three yak cows and 26 yak heifers were induced for oestrus synchronisation. Among them 52.8 and 30.8% showed fully synchronised oestrus, 18.8 and 30.8% incomplete oestrus, and 28.3 and 38.4% anoestrus, respectively. The results indicated that the calving period, fattening level (i.e. body condition) and types of hormonal preparations influenced oestrus induction.

Keywords: Hormone, oestrus synchronisation, yak

Introduction

Hormonal preparations pregnant mare serum gonadotropin (PMSG), luteinizing hormone (LH) and prostaglandin F-2 alpha (PGF2- α) have been investigated for oestrus synchronisation in yak cows. The results of these studies have shown that the oestruses of yak synchronised were in lower rates than the other bovine species. Yak is an animal well adapted to the ecological condition of highlands and has the peculiarity to become pregnant only between the summer and autumn seasons. The aim of this study was to find the opportunity to fertilise yak in large numbers through oestrus synchronisation.

Materials and methods

The oestrus of yak cows were synchronised by using PGF2- α (Prosolvlin, Intervet; Lutalyse, Upjohn) in 1.0 to 2.0 mL once intramuscular injection and the oestrous behaviour of treated animals were observed for 72 hours. Only cows showing anoestrus after the treatment were repeatedly injected on the eleventh day.

Controlled internal drug release (CIDR) containing progesterone (sponge, Hamilton) was inserted into the vagina of experimental animals for 10 days and 2.0 mL Prosolvin was intramuscularly injected two days before the CIDR removal. A full oestrus was also synchronised by intravaginal progesterone releasing intravaginal device (PRID) with

progesterone and krestar implantation in the ear for 12 days. The oestrus of the yak cows was detected with assistance of teaser bulls. Cows and heifers without corpus luteum in their ovaries were treated with 1000 IU of PMSG (Folligon, Auckland) and 2 mL of follicle-stimulating hormone (FSH; Super OV Rom) intramuscularly in order to promote ovarian activity during period of oestrous cycle.

Animals in oestrus were artificially inseminated twice in 8–12 hours interval. The results were analysed to examine the effects of calving period, age, live weight and hormonal treatments on the oestrous induction.

Results and discussion

Oestrus synchronisation was achieved in 43.7% of all yak cows treated with PGF2- α . Of the remainder, 25% had incomplete oestrous cycle and 31.3% were anoestrous. Among heifers treated with hormones only 15.4% were synchronised (Table 1).

Table 1. Oestrus synchronisation of yak with hormones.

Treatments	Age group	No.	Oestrus synchronised		Incompletely synchronised		Anoestrous	
			No.	%	No.	%	No.	%
PGF2- α	Cow	32	14	43.7	8	25.0	10	31.3
	Heifer	13	2	15.4	5	38.5	6	46.1
Progesterone sponge	Cow	13	9	69.2	1	7.7	3	23.0
	Heifer	5	4	80.0	1	20.0		
PMSG	Cow	4	4	100.0				
	Heifer	4	2	50.0	1	25.0	1	25.0
FSH	Cow	4	1	25.0	1	25.0	2	50.0
	Heifer	4			1	25.0	3	75.0
Total	Cow	53	28	52.8	10	18.8	15	28.4
	Heifer	26	8	30.8	8	30.8	10	38.4

Oestrus synchronisation rates in all animals were 69.2% and 80.0%, respectively, for intravaginal use of progesterone sponge and implantation in ear. The corpus luteum was completely degenerated for a favourable development of the follicles and the oestrus was detected within a shorter period after withdrawal of progesterone sponge.

The PMSG treatment resulted in 100% synchronisation of yak cows and 50% synchronisation of heifers. For FSH, only 25% of yak cows were synchronised and none of the treated heifers were synchronised. Thus, FSH alone had poor results.

Results from the four treatments were pooled together to examine effects of live weight, fattening level and days since previous calving (Table 2).

Among heifers weighing below 190 kg, 33.3% had incomplete oestrous cycle, 66.6% were anoestrous after the treatment while none was successfully synchronised. On the other hand, oestrus synchronisation rate of heifers above 190 kg bodyweight was 57.1%. Only

14.3% were anoestrous while 28.6% had incomplete synchronisation in this group. This result should probably be considered in relation to the stage of growth and fattening level of the animals. Of the 38 'reasonably fat' animals treated, 47.4% were fully synchronised, 15.8% were incompletely synchronised and 36.8% were anoestrous. Animals in 'poor' (fattening) condition, did not respond at all to the hormonal treatment.

Table 2. Effect of age, live weight, body condition and days after calving on synchronisation rates.

Influencing factors	No.	Oestrus synchronised		Incompletely synchronised		Anoestrous	
		No.	%	No.	%	No.	%
Age							
Cow	53	28	52.8	10	18.9	15	28.3
Heifer	26	8	30.8	8	30.8	10	38.4
Live weight of heifers (kg)							
>190	12	0	0	4	33.3	8	66.7
<190	14	8	57.1	4	28.6	2	14.3
Fattening level							
Good							
Cow	9	9	100				
Heifer	4	4	100				
Reasonable							
Cow	36	13	52.8	10	27.8	7	19.4
Heifer	12	4	33.3	8	66.7		
Poor							
Cow	8					8	100
Heifer	10					10	100
Days after calving							
<60	6	2	33.3	3	50.0	1	16.7
61-90	38	18	47.4	6	15.8	14	36.8
>91	9	8	88.9	1	11.1		

While the group treated less than 60 days after calving had 33.3% of the animals completely synchronised, 50% incompletely synchronised and 16.7% anoestrous, the respective rates of those treated 61-90 days post-parturition were 47.4, 15.8 and 36.8%. On the other hand 88.9% of animals treated more than 91 days post-parturition were successfully synchronised and only 11.1% were incompletely synchronised. These results indicate the need to delay synchronisation, after parturition, until animals have fully recovered from the previous calving and regained body condition.

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Experiment on oestrous synchronisation for artificial insemination with frozen semen in yak

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Summary

Irregular oestrus, silent oestrus, pseudo-oestrous and anoestrous in yak on the high and cold Tibetan Plateau pasture are very common and cause lower conception and calving rates, longer service period, dispersed service and calving, poorer production, and economic loss due to higher costs of labour and logistics. To solve the problems above, triplet hormones (containing testosterone propionate, luteosterone and estradiol benzoate), prostaglandin (PG) and follicle-stimulating hormone (FSH) No. 2 were used to induce oestrus synchronisation in 80 yak cows divided into 5 groups. The results showed that the 77.5% of the animals showed oestrus in 7 days after the treatments and resulting conception rate was 71.1%. Due to the low cost of the triplet hormones, it was used to treat another 780 yak in 1992. The conception rate in this second trial was 68.1%, twice that in the control group. These results suggest that oestrus synchronisation of yak should be an effective and practical approach in improving yak reproduction.

Keywords: Artificial insemination, frozen semen, hormone, oestrus synchronisation, yak

Introduction

There are 3.8 million yak in Tibet, one of the top five largest animal husbandry areas in China. Reproduction of yak, an animal exhibiting seasonal oestrus, is severely affected by altitude, temperature, humidity and nutrition under the extensive feeding and management systems. Normally, yak come to oestrus from July to October with a long service period but the conception rate is very low, especially in the drier years. This is because over 40% of the cows tend to have irregular oestrus, silent oestrus, pseudo-oestrus and anoestrus. Therefore oestrus synchronisation by external hormone treatments to prepare animals for artificial insemination (AI) in the extensive pastoral areas represents a possibility worth exploring. This study aimed to test and adapt a practical protocol of using a hormonal treatment regimen as a means of improving yak reproduction in smallholder herds.

Materials and methods

Trial phase in 1991

The study site was the Longren Village of Dangxun County. The area is located at an altitude of 4700 metres above sea level (masl), with an average temperature of 11.5°C, and with an annual rainfall of 280 mm and relative humidity of 65–75% in August and September. The summer pasture is good quality in terms of biomass and nutritive value.

A total of 240 cows ranging in age from 4 to 8 years were divided into three herds:

1. Herd A: 80 experimental cows were further subdivided into 5 groups for treatments with different hormones and doses by muscle injection:
 - a. Group 1: 4 mL triplet hormones (containing testosterone propionate, 25 mg; luteosterone, 12.5 mg; estradiol benzoate, 1.5 mg per mL), 2 mL PG and 100 µg FSH;
 - b. Group 2: 3 mL triplet hormones and 2 mL PG;
 - c. Group 3: 3 to 5 mL triplet hormones;
 - d. Group 4: 4 mL PG;
 - e. Group 5: 200 µg FSH (Table 1).

Animals failing to come into oestrus 7 days after the treatment were given a repeat injection.

2. Herd B: 80 cows, which came to oestrus naturally, were serviced by AI (Table 2);
3. Herd C: 80 cows, which came to oestrus naturally, were serviced by natural mating (Table 2).

Extension phase in 1992

Based on the preliminary trial and economic evaluation, 780 cows from four villages in the county were included in the treatment of the triplet hormones only and serviced by AI in the extension phase in 1992. A total of 5887 cows expressing natural oestrus and mating in the same areas were surveyed as controls.

Results and discussion

Trial phase

Among the 80 treated cows, 62 showed oestrus within 7 days following the injection of hormones. From the 76 cows involved in the AI, the conception and calving rates were 71 and 55%, respectively. Among the different groups, those treated with the triplet hormones, PG and FSH showed the best results: a total of 13 cows came to oestrus and were serviced by AI. The conception and calving rates were 100 and 73%, respectively. A

comparison of cows treated with single injections in the group, which got the triplet hormones, indicated that the latter had better conception and calving rates of 68 and 55%, respectively (Table 1).

Table 1. Oestrus synchronisation and AI in yak treated with different hormones.

Group	No.	Oestrus in 7 days after injection (No.)	AI		Conception		Calving (No.)	Reproductive rate (%)
			No.	%	No.	%		
1	15	15	15	100	15	100	11	73
2	15	15	15	100	10	67	10	67
3	20	16	19	95	13	68	11	55
4	15	9	15	100	9	60	6	40
5	15	7	12	80	6	50	6	40
Total	80	62	76	95	54	71	44	55

In herds B and C, 65 and 42 cows came to oestrus naturally. The conception and calving rates after AI and natural mating were 72% and 56%, and 67% and 40%, respectively for herds B and C (Table 2). Compared to the average calving rate (55%) for the oestrus-synchronised group, the average calving rate was even a little bit lower (48%).

Table 2. Data from cows showing natural oestrus and serviced by natural mating and artificial insemination (AI).

Service	No.	Oestrus		Conception		Calving (No.)	Reproductive rate (%)
		No.	%	No.	%		
AI	80	65	81	47	72	45	56
Natural	80	42	53	28	67	32	40
Total	160	107	67	75	70	77	48

Extension phase in 1992

After the trial phase, only the treatment with triplet hormones was selected for further extension in a large-scale trial due to its desirable results and lower cost compared to that of the treatment with the triplet hormones together with PG and FSH. The dosage for each cow was 2 to 3 mL of the triplet hormones (1 mL/100 kg body weight). From the experiences of the trial phase, AI was done only when cows come to oestrus the second time after the treatment. Among the 780 treated cows in four villages, 684 (88%) came to oestrus within 10 days after the injection, and only 531 (68%) cows that had a second oestrus were serviced by AI. The average service time was 54 days (39 to 61 days). The conception and calving rates were 80% (427/531) and 96% (411/427), respectively. In contrast, among the 5887 cows used as controls, only 1982 (34%) showed oestrus and natural mating was used. The service period was prolonged to 89 days.

The results of the large-scale trial (the extension phase) show that oestrus synchronisation could be successfully induced by treatment with the triplet hormones within a short time at a low cost in the field in smallholder herds. This can facilitate the use

of AI with frozen semen from top breeding bulls. These practices could be used to improve the yak reproduction and to provide better economic returns to farmers.

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Preliminary experiment to induce superovulation in yak

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Summary

Different hormonal treatments, including follicle-stimulating hormone (FSH) and pregnant mare serum gonadotropin (PMSG), were tested to induce superovulation in yak cows. During superovulation, the average numbers of follicles developed in the right and left ovaries of the cows ovulated were 5.36 ± 0.65 and 4.46 ± 0.43 , respectively, and the numbers of ovulated eggs from the right and left ovaries were 2.55 ± 0.30 and 1.94 ± 0.2 , respectively. Onset of donor's oestrus was detected on average, at 34.1 ± 0.52 hours after prostaglandin injection.

Keywords: Corpus luteum, follicles, superovulation, yak

Introduction

Studies have demonstrated that it is possible to produce multiple offspring from a highly productive female stock and this has been introduced into livestock breeding practices. The objective of superovulation in the female bovine animals is to obtain 6 to 8 transferable embryos from a highly productive donor. In Mongolia, embryo transfer has been successfully done in the Mongolian goat and Holstein cattle but only limited attempts have been made on the Mongolia native cattle and yak (Galragchaa 1993; Altankhuyag 1994; Begzjav 1995; Bulgaa 1996). This paper reports results of trials on superovulation of yak.

Materials and methods

Superovulation in yak cows was induced by the following hormonal preparations: FSH (Super OV Rom), PMSG (Folligon, Aukland), Anti-PMSG (Intervet), Progesterone (Sponge, controlled internal drug release (CIDR), Hamilton), and prostaglandin F-2 alpha (PGF2- α) (Lutalyse, Aukland; Prosolvin, Intervet).

The following combinations involving FSH preparation were investigated for induction of superovulation: 1) CIDR + Super OV + Lutalyse; 2) CIDR + Folligon + Lutalyse + anti-PMSG; and 3) CIDR + Folligon + Prosolvin.

Results and discussion

The outcomes of three treatments for superovulation were investigated by comparison of numbers of unovulated follicles and corpus luteum (Table 1). Comparison of the numbers of follicles in the ovaries from different treatments showed that there was no significant difference between the 1st and 2nd treatments. In the 3rd treatment, the number of follicles was less than those in the 1st two groups. Of all developed embryos 58.9% were found in the right ovary. The corpora lutea numbers in 1st two treatments were 4.8 and 5.0, respectively, but there were only 3.6 in the 3rd treatment.

Table 1. Effects of hormonal treatments.

Treatment	1	2	3
No. of cows	6	3	3
No. of follicles per cow	6.1 ± 0.6	6.0 ± 0.6	4.0 ± 0.6
Right ovary	3.5 ± 0.3	3.7 ± 0.3	2.3 ± 0.3
Left ovary	2.5 ± 0.3	2.3 ± 0.3	1.7 ± 0.3
No. of corpus lutea per cow	4.8 ± 0.3	5.0 ± 0.6	3.6 ± 0.3
Right ovary	3.0 ± 0.6	2.7 ± 0.3	2.0 ± 0.0
Left ovary	1.8 ± 0.3	2.3 ± 0.3	1.7 ± 0.3
Oestrus time after PGF2- α injection (hour)	34.7 ± 2.8	33.0 ± 1.2	34.7 ± 0.4

Superovulation was induced in all six donors of the 1st treatment by FSH and the average number of ovulated ova was 4.8. In the 2nd treatment with PMSG and anti-PMSG combination, 5.0 eggs were ovulated, on average, while in the 3rd treatment 3.6 ova were ovulated by PMSG. The right ovary shared 2.55 ± 0.3 of all ovulated ova. The corresponding figure was 1.94 ± 0.2 for the left one. The corpus lutea formed in the right ovary amounts to 57.1%; the remainder were formed in the left ovary.

The oestrus onset took place at 34.7 hours after PGF2- α injection in the 1st and 3rd treatment, while the onset was 33 hours in the 2nd treatment. Proctoscopic examination of the numbers of follicles and corpus luteum in the ovaries of three cows treated with FSH confirmed the results from rectal palpation. Morphological and qualitative evaluation of three embryos recovered from a donor revealed that two embryos out of the three embryos were transferable.

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Light microscopic investigations of frozen-thawed yak semen—A pilot study

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Summary

A simple, light microscopic sperm staining method was used for simultaneous evaluation of acrosome integrity, viability and morphology of sperm cells of wild and wild × domestic F1 yak bulls.

Keywords: Light microscopy, sperm quality, yak

Introduction

A simple sperm staining method is used routinely for simultaneous evaluations of acrosome integrity, viability and morphology in Hungary (Kovács and Foote 1992). The aim of this pilot study was to try this method for frozen-thawed yak semen and to get some basic information for a wide-scale investigation on wild and domestic yak semen quality.

Materials and methods

Staining solutions

Viability testing stain: 0.20% trypan blue (prepared from 0.4% trypan blue, Sigma T 8154 diluted 1:1 with 0.9% NaCl). This solution is stable for several months at room temperature.

The fixative is composed of 86 mL of 1 N HCl plus 14 mL 37% formaldehyde solution and 0.2 g neutral red (Sigma N 2880). It is stable for about two months at room temperature and may be used repeatedly.

The acrosome stain is 7.5% Giemsa stock solution (Sigma GS 500) in distilled water prepared freshly before use.

Staining procedures

Ten samples of frozen yak sperm (three wild and seven wild × domestic F1 yak) were thawed and diluted 10× with 0.9% NaCl at 38°C (two pellets to two mL NaCl-solution).

Equal drops of 0.2% trypan blue, and diluted semen were mixed on slides with the edge of another slide and smeared. They were air-dried in a near-vertical position at room temperature. They were fixed for 2 minutes. Slides were rinsed with tap and distilled water, and stained in Giemsa solution at room temperature overnight. They were rinsed with tap and distilled water, differentiated in distilled water for 2 minutes, and air-dried.

Following mounting with DPX (BDH, 360294H) and coverslipping, stained smears were evaluated by a light microscope at 400× magnification using a 40 × objective. Three hundred spermatozoa per slide were counted.

Classification

For live/dead assessment, the posterior, for the status of the acrosome, the anterior part of the sperm head provides information (Kovács and Foote 1992).

Morphologically abnormal sperm cells were classified according to Barth and Oko (1989).

Results and discussion

With this staining method, all sperm cell types described previously for other domestic animal species were clearly distinguished (Figure 1), including stained—membrane damaged—sperm tails (Nagy et al. 1999).

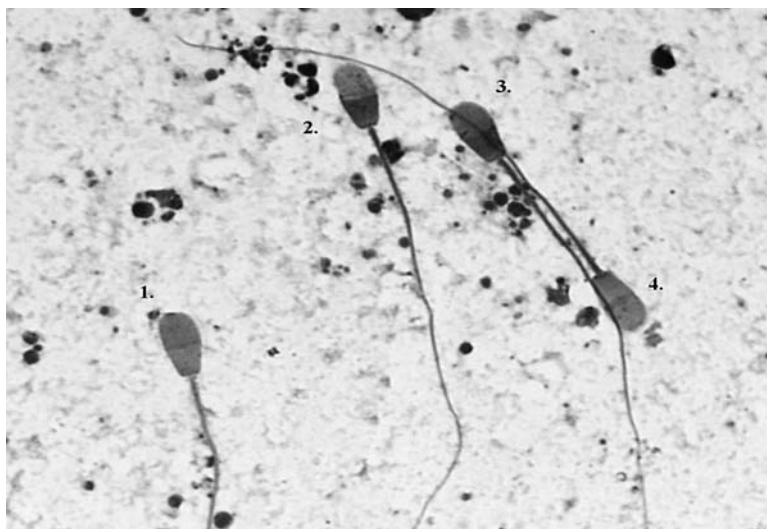
Du (1987, cited by Cai and Wiener 1995) and Lu and Zhang (1994) mentioned the low rate of morphological abnormalities in the wild yak semen. In this study, the average rate of sperm head and tail defects and cytoplasmic droplets were 1.3%, 2.6% and 0.1%, respectively. The rate of total sperm defects was 4.0% (2.0–8.3%).

Percentage of 'live' (intact head, tail, and acrosome membrane) spermatozoa without morphological abnormalities can be a practical index of semen quality.

On the basis of the results and experiences of this pilot study, a larger project could be planned to make comparisons of wild and domestic yak semen samples, and to investigate the effect of the freezing method on the quality of the semen.

Acknowledgements

The authors are grateful to Prof Lu Zhonglin for kindly supplying the frozen semen for this study.



1. 'Live' cell, intact acrosome, unstained tail.
2. 'Dead' cell, lost acrosome.
3. 'Dead' cell, loose acrosome.
4. 'Live' cell, damaged acrosome, stained tail.

Figure 1. Yak sperm cells, Kovács-Foote staining.

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Experiments on sexing yak spermatozoa by fluorescence *in situ* hybridisation using bovine Y-chromosome specific DNA probe

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Summary

Y-bearing bovine spermatozoa may be distinguished by fluorescence *in situ* hybridisation (FISH) using specific DNA probe, offering an *in vitro* control of experiments for producing sex-oriented or sex-specific semen. Bovine Y-specific probe gave distinguishable signal also in yak spermatozoa. Specific binding of the probe to the corresponding sex chromosome was confirmed on yak chromosome preparations.

Keywords: Cattle, fluorescence *in situ* hybridisation, sexing, spermatozoa, yak

Introduction

Cattle (*Bos taurus*, L.) and yak (*Bos/Poephagus grunniens*, L.) are two related species having identical diploid chromosome number ($2n = 60$; Krallinger 1931; Zuitin 1935). The autosomes are all acrocentric, the X-chromosome is a large sub-metacentric in both species, the Y-chromosome of yak is small sub-metacentric (Popescu 1969; Kovács et al. 1982) demonstrating some polymorphism (Gang et al. 1991 cited by Jianlin 1996), similar to European cattle (*Bos taurus typicus*).

Y-bearing cattle spermatozoa may be identified by fluorescence *in situ* hybridisation (Hassanane et al. 1998; Tardy et al. 1998; Hassanane et al 1999; Révay et al. 2000). Based on the morphologically similar sex-chromosomes, we tried to apply bovine Y-specific probes for sexing yak spermatozoa. Our goal was to elaborate a rapid and effective *in vitro* technique to control the experiments on producing sex-oriented yak semen (Cao et al. 1996).

Materials and methods

Sample preparation

Frozen/thawed yak semen doses were diluted with 0.9% NaCl, smeared, air-dried in China and mailed to Hungary. To facilitate the penetration of the probe and better signal visualisation, sperm heads were decondensed with papain-dithiothreitol solution (Schwerin et al. 1991; Hassanane et al. 1999).

Chromosome preparations were made from blood taken from a yak bull in Hungary (Moorhead et al. 1960).

Preparation of chromosome specific hybridisation probe

The Y-chromosome specific probe was prepared by polymerase chain reaction (PCR) method. The primers are specific to the BC 1.2 region on the bovine Y-chromosome (Cotinot et al. 1991; Schwerin et al. 1991). The reaction was carried out using bovine male genomic DNA as template. The sequences of the oligonucleotide primers were: 5'ATC AGT GCA GGG ACC GAG ATG 3' and 5'AAG CAG CCG ATA AAC ACT CCT T 3'. The PCR was performed as described by Kobayashi et al. (1998) with modified MgCl₂ concentration (1.2 mM). The 250 bp product was labelled with biotin-16-dUTP during the PCR.

Fluorescent *in situ* hybridisation

FISH was performed as described by Pinkel et al. (1986) with slight modifications. The biotin labelled probe was detected with the Tyradmide Signal Amplification System (Direct FITC, NEN Life Sciences) according to the manufacturer. The slides were examined under a fluorescent microscope (Zeiss Opton) with simple microscopic observation.

Results and discussion

Decondensation of yak spermatozoa needed a prolonged treatment as compared to cattle; 15–25 vs. 3–6 minutes. The bovine Y-probe produced strong signals in decondensed yak spermatozoa (Figure 1). Specificity of the probe was confirmed on yak metaphase chromosomes: the Y-chromosome was labelled with the probe, and there was no signal on the autosomes (Figure 2).

We can conclude that it is possible to use the bovine Y-probe to control experiments on producing sex-oriented yak semen. Further effort will be needed to prepare bovine X-chromosome specific DNA probe, which is easy to produce and allow simultaneous detection of both the sex chromosomes on yak spermatozoa.

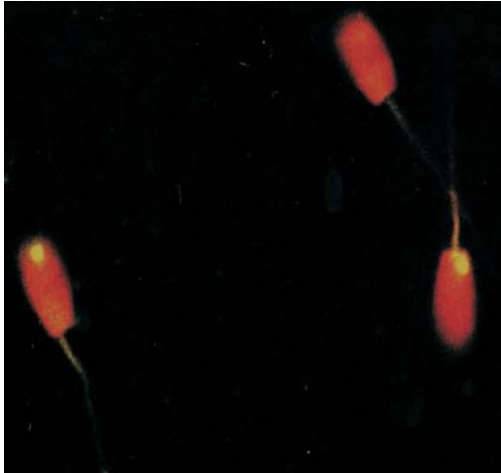


Figure 1. Detection of the bovine Y-probe on yak spermatozoa.

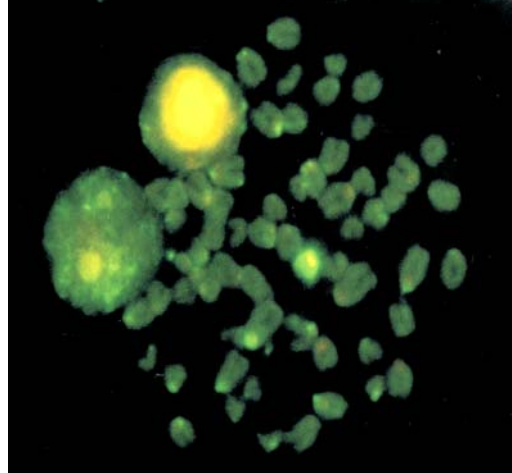


Figure 2. Detection of the bovine Y-probe on yak metaphase chromosome preparation.

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Artificial insemination trial in yak in Bhutan

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Summary

Yak play a significant role in the economy and social life of the people of Bhutan. The Department of Agriculture and Livestock Support Services supported the yak herders by distributing yak bulls procured from places in other breeding regions within Bhutan with the aim to mitigate the level and effects of inbreeding. To improve the productivity of Bhutanese yak, about 1000 doses of Chinese yak semen were obtained under Helvetas funding through Food and Agriculture Organization of the United Nations (FAO). The artificial insemination (AI) in yak was carried out from 1990 to 1997. A total of 82 inseminations were implemented and 45 progenies recorded. The phenotypic characters of the AI progenies are summarised in this paper as well as some discussions on breeding habits of yak in their natural habitat. The trial also highlights the practical difficulties faced by the field veterinarians and livestock extension workers to undertake such tasks that affect the success rate and AI coverage. From the experiences gained from the trial, the implementation of yak AI on a full scale is not recommended until concrete results are obtained.

Keywords: Artificial insemination, Bhutan, yak

Introduction

Yak play a very important role in the economy and social life of the people of Bhutan. They are an integral component of the pastoral system in Bhutan. Yak are multi-purpose animals and provide milk, butter, cheese and meat for family consumption as well as for sale or barter in exchange for food grains and goods. They also provide hide, hair and wool, which are used for making clothes, tents, blankets, ropes and many other household items. Yak husbandry is an age-old practice and the only means of livelihood for many people living in high altitude areas.

Bhutan's Department of Agriculture and Livestock Support Services (previously Animal Husbandry Department) supported the yak herders by distributing yak bulls procured from places in other breeding regions with the aim to mitigate the level and effects of inbreeding (Gyamtsho 1996). To improve the productivity of Bhutanese yak, 1000 doses of Chinese yak semen were obtained under Helvetas funding through FAO.

Materials and methods

The trial on yak AI was carried out in different regions on a limited scale from 1990 to 1997. As there is no motorable road to reach the yak herds, the frozen semen using medium sized storage containers that could last for a month was carried by porters requiring a minimum of two days walk to reach the yak herds. Oestrus in yak is seasonal with most of the females coming to heat during the month of July and August. The trial was carried out during this period to cover maximum females. The hind parts of the inseminated females were covered with locally made raincoat (*Chaleb*) to prevent natural service by breeding bulls. A total of 82 inseminations were carried out including pure yak semen as well as Tarentaise semen. Tarentaise semen was used in the trial to produce Zo and Zom and to confirm the success of AI in yak. All the progenies were ear tagged and each progeny was physically examined to determine phenotypic difference from the existing yak population.

Results and discussion

A total of 82 inseminations were carried out and 45 progenies were recorded. The phenotypic differences observed and yak herders view on yak × yak AI progenies were as follows:

- fore and hind limbs bigger in size
- more hair growth on dorsal ridge and tail
- higher growth rate
- larger and longer horns
- more docile-cannot withstand heavy snowfall.

The Tarentaise progenies did not look to be typical Zo and Zom. However, the phenotypic differences observed in yak × Tarentaise progenies were as follows:

- difference in horn pattern
- the horn shape intermediate to parental type and curved were out
- hair coat shorter and finer than that of yak
- more hair on the flank, thighs and chest
- brown ear lobes.

Usually the breeding season lasts from June to September with most of the females coming to heat during the months of July and August (Tshering et al. 1996). The seasonal oestrus may be due to improved nutritional status during summer months or may be due to increased day length. During the breeding season female yak are seen in heat in the morning and evening or on cloudy days after rain. Detection of heat without a yak bull is quite difficult.

The local method of restraining yak i.e. tying the fore limbs is very effective. Under this method of restraint, yak do not kick, although they make jumping movements. During the breeding season the breeding bulls become ferocious and it was quite difficult to separate the inseminated female yak from the bulls. Although, majority of the herders were of the view that the *Chaleb* was very effective in preventing mating by breeding bulls, there were few

herders questioning the efficacy of this method as some breeding bulls were able to remove it by use of their horns.

The experience gained from the AI trial in yak indicate that the technology should not be implemented on a full scale due to the following reasons; i) as there is no motorable road to reach the yak herds, transportation of frozen semen and liquid nitrogen is very difficult, and ii) separation of breeding bulls from the herd/tying of the inseminated female yak till oestrus is over is not at all possible. Under such circumstances one cannot be completely sure that the progenies born are from AI.

the performance of AI progenies in terms of milk production needs to be studied in future. As the scope for AI in yak is limited by practical constraints, the other countries seem to be a viable option to improve yak productivity in Bhutan.

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Fertility of Mongolian female yak inseminated with frozen semen of wild yak

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Summary

Wild yak frozen semen, imported from P.R. China, was used in an experiment on artificial insemination (AI) technique in Mongolian female yak to evaluate the conception rate and obtain 1/2-hybrid progenies. Female yak showing natural (n = 20) and synchronised (n = 20) oestrus were inseminated twice at a 12-hour-intervals. The conception rate of cows calculated on the bases of numbers of calves born was 35.0 and 40.0%, respectively, for the 'natural' and synchronised groups.

Keywords: Artificial insemination, fertility, frozen semen, Mongolian yak, wild yak

Introduction

Implementations of new breeding techniques have led to an increase in the production and reproductive efficiency in yak husbandry (Wei 1994). Some results have shown that the number of calves born were 92.3% for naturally mated yak cows, while artificial insemination (AI) with wild yak frozen semen has resulted in a figure of 66.1%. Many factors have been shown to influence the conception rate of yak cows on AI (Ben et al. 1994; Pang and Qiao 1994; Zhao and Zhang 1994). This paper reports the results of introducing the wild yak semen to Mongolian domestic yak through the AI approach.

Materials and methods

Cows showing natural (n = 20) and synchronised (n = 20) oestrus were inseminated twice at a 12-hour-interval. The frozen semen pellet was thawed at 38°C water for 1 minute. The sperm motility before the insemination was examined, and only semen with motility above 0.4 was used for insemination. At insemination, the thawed semen was deposited in the cervix.

Results and discussion

The heat in experimental cows was detected through the use of vasectomised males daily and those showing clear signs of heat were inseminated.

A small difference between the two groups in terms of conception rate suggested that both frozen semen and AI techniques work well enough to achieve a reasonable level of conception (Table 1). However, the pregnancy rate in the present study was much lower than that reported by Zhao and Zhang (1994). The difference may be due to the fact that, in the present study, the technical staff involved had much less experience in AI techniques in yak and their ability to detect oestrus was generally poor.

Table 1. Conception rate of cows inseminated with wild yak frozen semen.

Groups	No. of cows	Conception rate	
		No.	%
Animals showing natural oestrus	20	7	35.0
Animals with synchronised oestrus	20	8	40.0
Total	40	15	37.5

The gestation period in the experimental cows was 249 ± 14.5 days and the mean body weight of calves at birth was 14.4 ± 0.81 kg.

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Use of herbal medicine for anoestrus management in yak (*Poephagus grunniens* L.)

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Summary

Reproductive rate in yak is low in the natural habitat of high altitude due to several factors, principal ones being winter stress and nutritional deficiency. Age at first service and post-partum anoestrus are major problems that result in small calf crop and long calving intervals. Generally, yak reproduce in alternate year due to short breeding season. Hormonal management of anoestrus is costly and requires expert examination of the animal. This is not possible in the yak due to mobility of herds and inaccessibility of the grazing areas.

In this experiment, herbal drug and mineral supplementation were tried in true anoestrus yak in randomly selected animals.

- Group I: Control animal with normal concentrate ration plus dry grass and green fodder.
- Group II: Normal ration plus Cyclomin 7 tablets (Alved, Mineral supplementation Bolus) one bolus for seven days.
- Group III: Normal ration plus Cyclomin 7 tablets followed by *Prajana* (Indian herbs, Herbal oestrus induction preparation) two boluses for three days.

Only 20% of the animals in Group I came to heat in the same breeding season and 40.6% of the animals came to heat in Group II on first treatment while total oestrus percentage increased to 55.8% on subsequent treatment with the same medicine to the non-responders after fifteen days. However, in Group III, 78.7% of the animals showed oestrous symptoms after first treatment and after repeating the treatment to non-responders total oestrus percentage increased to 86.4%. Small amount of concentrate, mineral supplementation and use of *Prajana* treatment can manage anoestrus condition in yak efficiently.

Keywords: Anoestrus, Cyclomin-7, herbal medicine, *Prajana*, yak

Introduction

Delayed sexual maturity, post-partum anoestrus and seasonal breeding are major problems in the field condition in yak. The main reason for anoestrus in yak is nutritional deficiency

as the yak survive solely on grazing. The age at sexual maturity, post-partum anoestrus and calving intervals are very high in yak (Pal 1993; Mohanty 1997). These problems can be eliminated in the field condition by modest supplementation with concentrate feeds, conservation of fodder for crisis feeding and provision of mineral supplements. Traditional indigenous veterinary remedies are routinely practised in animal treatment particularly in rural areas. Hormonal management of anoestrus is costly and requires examination of the animal by experts. This is impossible due to inaccessible yak tract. Standardisation of pharmacology of clinically proven drugs in animals has already been initiated such formulations as *Prajana* (Indian Herbs), Janova (Dabur Ayurved Ltd), Aloes compound (Vet) (Alersin), Sajni (Srabhai Chemicals) for use in different animal species. These formulations are potent combinations of herbs formulated scientifically to induce ovarian activity in anoestrus animals. Action is closely similar to gonadotrophin and helps release of hormones for inducing ovulatory oestrus. The objective of the present study was to evaluate one such formulated drug in combination with mineral supplement to induce ovulatory oestrus in post-partum anoestrus yak.

Materials and methods

A total of 30 post-partum anoestrus primiparous yak were selected from the yak herd of National Research Centre on Yak, Dirang, Arunachal Pradesh, managed in semi-range system over a three-year period. Yak in the farm were supplemented with normal concentrate, hay and green fodder throughout the year. These animals were examined by rectal palpation to monitor activity of ovaries at every 15 days interval. They were also closely observed for signs of oestrus. The trial consisted of three experimental groups: Group I, 10 animals were assigned without any treatment and were kept on normal feeding regimen; Group II, eight animals were treated with Cyclomin-7 tablets for seven days and examined for the ovarian activity. Those which did not come to heat were given repeat treatment with Cyclomin-7 after 15 days and examined for ovarian activity; Group III, 12 animals were first treated as Group II and after treatment were supplemented with 2 tablets of *Prajana* for three consecutive days and non-responders were treated again with *Prajana* after 15 days and evaluated for ovarian activity.

The compositional details of the preparations/drugs used in the study were: *Cyclomin-7* tablets have Cobalt-14 mg, Copper-174 mg, Iodine-35 mg, Iron-350 mg, Manganese-140 mg, Selenium-1 mg, Zinc-70 mg; and *Prajana* (Indian herbs)—contains extracts of *Citrullus cococynthis*, *Piper nigrum*, *Piper longum*, *Zinziber officinale* and *Sesamum indicum*.

Results and discussion

Only 20% of the animals in Group I came to heat in the same breeding season and 40.6% of the animals came to heat in Group II on first treatment, while total oestrus percentage increased to 55.8% on subsequent treatment with the same medicine to the non-responders after fifteen days. However, in Group III, 78.7% of the animals showed oestrous symptoms

after first treatment and after repeating the treatment to non-responders total oestrus percentage increased to 86.4%. The mean time interval from treatment to oestrus was around 12 to 14.5 days in all the groups. The mean conception rate was very high—up to 85%—in all the groups.

Several indigenous drugs marketed by Indian pharmaceutical companies have been studied in cattle and buffaloes with very high rate of success. These include results reported for *Prajana* (Patil et al. 1983; Kodagali et al. 1991), for *Heatinee* (Nemade et al. 1994), for *Estron* (Shah and Derashri 1985), for *Moralac* tablet (Dhoble and Markandeya 1995), MAU drug (Dhavale et al. 1998; Nisoli et al. 1991), all of which are in agreement with the present findings. The high success with *Cyclomin-7* indicates that there is deficiency of some of the trace element playing important roles in the high incidence of anoestrus in yak. In the combination therapy with *Prajana*, the success rate was very high which clearly indicates that mineral and hormonal disturbance is the major cause of very high incidence of post-partum anoestrus in yak. This is in agreement with the findings of Sharma et al. (1996) in heifer and cows. This treatment may be helpful in heifers to initiate oestrus cycles at an early age, thus reducing the age at first calving in yak, which are seasonally anoestrus due to nutritional deficiency and climatic stress. Anoestrus condition in yak can be managed efficiently by mineral supplementation and use of *Prajana* treatment to improve the sexual maturity and reduce the calving interval in yak heifers and cows.

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Session V: Environment and physiology

Adaptation of yak to non-typical environments: A preliminary survey of yak in North America

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Summary

Yak have generally been described as particularly well adapted, anatomically and physiologically, to cold climates and high elevations. It has also been widely inferred that yak will not perform well, or even survive, in environments, which are markedly different from the traditional, noting especially an intolerance to high ambient temperatures. This view may need revision in the light of the successful spread of yak to a wide variety of environmental conditions in several parts of the world and most especially in North America over the past decade, albeit in still relatively small numbers and small herds. There are around 90 commercial breeders of yak in the USA and Canada with herds varying in number from less than ten breeding females to in excess of 400. Yak are bred pure, but yak bulls are also used to cross with other cattle. The primary aim is lean meat production, but fibre is also prized. In some areas, yak are also trained for packing. Yak in North America are not restricted to the cooler mountainous regions, although these predominate and include some of the larger herds. Some herds are in coastal regions and in relatively low-lying areas with climates that are temperate or warm for much of the year. Birth weights of calves are said to vary from 13 to 27 kg. Under good conditions, calves weaned at 4–5 months old can weigh 70 kg. Females on the best farms are first mated at 18 months of age, though 2 to 2.5 years is more common. Most of the cows calve every year. The adult weights of females vary from 240 to 360 kg and bulls from 550 to 680 kg.

Keywords: Adaptation, North America, performance, yak

Introduction

Six yak were imported to Canada in 1909 though only 1 male and 3 females survived to the following year. The yak did not initially reproduce but after being moved to different, colder locations, a small population of yak was built up. Two centres commenced breeding experiments: at Buffalo Park, Wainwright, where the main emphasis was on hybridisation experiments with American bison and domestic cattle, and at Fairbanks Experiment Station in Alaska where the aim also included crossing with domestic cattle. The various

trials were suspended by 1930 (Deakin et al. 1935; White et al. 1946). Yak, however, survived in National Parks and zoos. It is likely that the present population of yak in Canada and the USA are derived from this foundation—although there are also unconfirmed reports of yak derived from an importation to Bronx Zoo in 1890 and possibly elsewhere.

Yak are also known to exist in a number of zoos around the world outside their main areas, and a successful small herd has been at Whipsnade Wild Animal Park in England since the 1940's from whence small satellite herds have been set up (Cai and Wiener 1995). Small numbers of yak are also kept in a commercial setting in New Zealand. This may not be a complete list.

The existence and relative success of yak in environments, which must be regarded as non-traditional for yak suggests an adaptability of yak to a wide variety of climatic and environmental conditions.

The purpose of this report is to draw attention to the present status of yak in commercial herds in the USA and Canada and to provide some very limited and preliminary records of performance.

Material and methods

About 70 owners of yak herds in North America are members of a yak breed association—the International Yak Association (IYAK). In addition, there are some other herds not affiliated to the Association. The latter are likely to be fewer in numbers and with relatively few animals. Sixteen of these non-affiliated herds have been located and are included in Table 1, which shows their distribution by State, but, in addition, there could be other herds. The total number of yak in these various herds has been estimated at around 2000, of which about half are breeding females and there are said to be an approximately equal number of crossbreds (yak × various breeds of cattle). However, the numbers are not precisely known.

About two-thirds of all the herds affiliated to IYAK were contacted by mail, but only a small proportion responded. Apart from the geographical distribution of the herds, as shown in Table 1, other information is restricted to those herd owners. Information was sought on the origin and size of each herd, its management, farm environment, breeding policy, and any available information on performance and marketing. Not each response was complete in every respect.

One herd owner in New Zealand was also contacted and provided information.

Results

Distribution and environments of herds

Table 1 shows the distribution of yak herds by country and State. It can be seen that the distribution stretches from British Columbia and Alberta (Canada) in the north to Arkansas (USA) in the south, and from the Oregon coast in the west to New Hampshire in the east. One correspondent referred to a herd in Alabama, but this was not verified.

Table 1. Location of yak herds in the USA and Canada, by State.¹

Location	Number of herds	No. Providing data
USA		
Arkansas	3	
California	2	
Colorado	10	5
Idaho	4	1
Indiana	1	
Iowa	1	
Kansas	1	
Kentucky	1	
Massachusetts	1	1
Michigan	5	
Minnesota	1	1
Montana	3	
Nebraska	5	1 ²
Nevada	1	
New Hampshire	1	1
New Jersey	1	
New York	3	
North Dakota	1	
Oregon	10	1
South Dakota	1	
Virginia	2	
Washington	9	1
Wyoming	1	
Canada		
Alberta	13	2
British Columbia	5	2

1. Includes 16 herds not affiliated to IYAK. The number and location of any other such herds is not available.

2. The largest herd in the USA.

Many of the herds in States adjacent to the Rocky Mountain range are on ranches at elevations up to around 2600 metres above sea level (masl), typified by cool summers and cold winters but the majority of herds, even in the mountainous regions, are at lower elevations with hotter summers. In other States, it is common to have yak in hill areas up to perhaps 700 masl, but a few are located at little above sea level, as well as coastal areas—including a small island off Vancouver Island. The herds in coastal areas will experience few if any frosts in winter with little or no snow and a fairly high rainfall spread throughout the year.

The single largest herd of yak in the USA, numbering in excess of 800 head, and an equal number of yak crosses with domestic cattle, is situated in Nebraska east of the Rocky Mountain range at an elevation of 1280 masl and with an annual precipitation of 420 mm.

A small herd of yak (but one of several) in New Zealand, for which contact was made with the owner, is located at the northern end of the South Island. It is only a short distance from the sea, 40 masl, and has a summer temperature that can exceed 30°C and mild winters. Annual precipitation is 2500 mm.

Characteristics and performance

Four coat colour types are described—all black, black with some white markings (called trim) which predominates, black and white (described as ‘royal’) and a ‘gold’ colour, said to be recessive to black, which is present in small numbers.

Birth weights of yak calves are typically quoted as varying from 13–27 kg. Weaning weights generally at 4–5 months of age, were quoted as 65–70 kg for some farms presumed to be providing above average rearing conditions. Adult weights of yak cows were given in the range 240–360 kg and yak bulls 550–680 kg, though one yak bull in Canada was reported to weigh 820 kg.

Some females were mated for the first time at 18 months of age but 2–2.5 years is more typical. Calving annually is the norm, but one of the herd owners noted that half his yak cows had only 2 calves in 3 years. Bulls are not generally used for mating until 3 years old, although some younger ages were reported.

Few health problems were encountered but the need for routine vaccinations and deworming, especially in humid conditions, was referred to by several of the herd owners.

Feeding and management

Most of the herd owners stressed that natural grazing in summer and hay in winter represented most of the feed. Some gave small supplements of grain. All provided mineral blocks and some mentioned a need for an adequate amount of copper in the block to promote health and the breeding of the yak (Cai and Wiener 1995).

Reference was made by many of the herd owners to the feed efficiency of their yak relative to other cattle and hence to the relatively small quantities of feed and pasture required per kg live weight of animal.

For the most part, yak were kept out-of-doors the year round. One of the owners of a small herd referred to the provision of winter housing, but with only moderate success. In general, yak were regarded as reasonably tame and, with few exceptions, easily handled and easily confined by fencing.

Possible heat stress for yak was mentioned but did not amount to a problem. The animals sought some shade and water-cooling in periods of high heat in summer but reference was made to one farm (not contacted) where even this was not found necessary.

Uses and marketing

Most of the yak were kept for breeding and the sale of breeding stock. Bulls were also sold for this purpose and for crossbreeding to other cattle. The leanness of yak meat and the

efficiency of feed conversion of both pure and crossbred yak are stressed in the promotion literature. Crossbred males are all sold for meat.

A few yak are trained for packing and trekking, particularly in the vicinity of the Rocky Mountains. Some specialist attention is given in some of the small herds to the yak wool and hair for weaving—the undercoat wool fetching a high price. Milk is mentioned in the promotional literature but there were no reports of currently successful milking and milk processing. A few of the yak are sold as farm ‘pets’. A few ‘collectors’ value hides, heads and horns.

Discussion

The performance data provided were not extensive and are unexceptional. Since strict averages of performance data are not available, it is difficult to compare the results from the USA with corresponding published data from, say, China. On the face of it, the range of birth weights of yak calves provided suggests that they might be a little above those expected in traditional yak areas. Also, the inferred growth rate of calves to weaning, perhaps exceeding 400 g per day, is also higher than the gains of around 300 g previously quoted (Cai and Wiener 1995). However, the calves here are reared under what should be regarded as good conditions and with access to all the maternal milk, whilst traditionally the herders took some milk for domestic consumption—thus restricting the intake by the calf. In one comparison made by Zhang (1985), yak calves given access to all their dams’ milk gained 439 g per day over 159 days, compared with 395 g and 195 g for calves which had dams that were also milked either once or twice a day, respectively. Some of the adult weights, particularly of breeding bulls, appear slightly higher than usually reported for domestic yak (Joshi 1982; Cai and Wiener 1995; Lensch et al. 1996). The herds’ surveyed reported higher reproductive rates for their yak than are common in the more traditional circumstances.

Two matters of genetic interest arise from the spread of yak in North America and elsewhere. They concern the numerical size and nature of the genetic base for these populations and their adaptation to new environments.

The only documented evidence available to the author concerning the origin of yak in North America, suggests the possibility that all are descended from three of the yak cows and one of the two yak bulls imported to Canada in 1909. In numerical terms, over a period of 90 years, the expansion to the present population is entirely feasible, given the expectations for reproductive rate and generation interval. This would suggest, however, a close relationship among the animals existing. In addition, however, there is rumour of other, independent sources of yak blood entering the population; but these will need to be investigated and confirmed. It is also highly likely that some of the crossbreeding of yak with other cattle has led to the introduction of some *B. taurus* genes into the American yak gene pool. DNA analysis should be able to provide evidence for or against such infusion.

Some of the yak in North America are kept in environments, which, on a traditional view, could be regarded as alien for yak, most especially those near the Pacific coast. It has to be borne in mind that the yak is regarded as particularly well adapted to cold, relatively dry climates at high elevations and with relatively poor, highly seasonal feed supply. Many of the

herds in North America are in mountainous areas. A better supply of feed even in these areas, especially in the winter, than is common in the traditional yak lands adjacent to, and to the north of, the Himalayas, can be taken to account for the higher reproductive rate and better early growth rate.

It is the herds in coastal areas, including the herd reported in New Zealand, and those in low-lying temperate or warm environments, which call for comment. Even in these situations, the yak appear to perform and reproduce well, without suffering debilitating stress. Cai and Wiener (1995) reported that the situation correspond to the yak herd at Whipsnade in England and for the apparent success of yak in zoos and wild animal reserves in various parts of the world. It needs to be asked, therefore, whether such yak differ genetically from domestic yak in, for example, China, or whether the special adaptive characteristics of the yak to cold and harsh conditions do not inhibit life in warmer and gentler environments.

There is, of course, a possibility that genes that may have been introduced from crossbreeding with other cattle may include genes for adaptation to the new environments. In the case of yak, any such introduction of genes must come through crossbred females, as the crossbred males are sterile. The process of crossing, however, seems too random, too varied and selectively non-deliberate to provide a satisfactory explanation for adaptation, without much further evidence. Moreover, in the short period of 90 years or so under consideration, even if genes for adaptation to new environments had been introduced, they would have required strong positive selection pressure to spread throughout the population. Future DNA analysis should provide an answer at least to the extent of any introgression, but is less likely to resolve the nature of the genes introduced in relation to adaptive characteristics.

It would be altogether simpler to hypothesise that yak are not intrinsically unable to survive and reproduce in a wide variety of environments. It would then be necessary to explain why in the principal areas for yak production in China and adjacent countries, the yak, the cattle and the crossbreds generally occupy different strata of territory. Yak are generally predominant, even exclusive, at the highest elevations where intrinsic adaptation to the harsh environment is of paramount importance. Cattle are at the lower altitudes where they are capable of expressing their higher potential for productivity. The crosses in the intermediate locations benefit from both adaptation and production characteristics of their respective yak and cattle parents, as well as benefiting from any hybrid vigour that may be generated. In the present context of yak in North America and other 'new' environments, however, it seems that yak are not by nature inhibited from thriving in 'cattle country'. The converse, however, of the adaptation of cattle to traditional 'yak country' is unlikely, as *B. taurus* and *B. indicus* cattle are absent from the regions which require the ability to withstand the greatest extremes of cold and oxygen deprivation and of feed shortage in winter and early spring.

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Endocrine changes and their relationships with bodyweight of growing yak

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Summary

Concentrations of growth hormone (GH), insulin, thyroxin (T_4) and 3,3',5'-tri-iodothyronine (T_3) in blood samples of growing yak during different seasons were determined by radio-immunoassay. Changes in bodyweight of the growing yak and compositions of grass were also measured. The seasonal changes in hormones were significant (at least $P < 0.05$). In the same season, variation in hormonal concentration was affected by the growth stage of the animal. The bodyweight gains varied in different seasons, with significant increase from May to September and decrease from January to May. Correlation analysis indicated that T_4 had a significant positive correlation with bodyweight of the growing yak ($r = 0.323$, $P < 0.05$), but other hormones did not have significant correlations with bodyweight. The results show that annual cycle of weight loss and gain is attributable to the seasonal changes in feed supply and that the seasonal changes in the concentrations of the assayed hormones were indirectly dependent on grass growth.

Keywords: Body weight, correlation, growth, hormone, yak

Introduction

Yak (*Bos grunniens*) is one of the unique domestic animals living on the Qinghai-Tibetan Plateau. Its dominance in this area is attributed to its great adaptation to high altitude, anoxia condition and feed shortage in cold seasons. It provides important products for the herders who live in the area. Due to cyclic nutrient deficiency or unbalanced nutrient supply within short growing seasons for herbage growth, annual cycle of weight loss in cold season and weight gain or compensatory growth in warm season in yak is a common phenomenon.

We knew that endocrine activity regulates animal nutritional balance and growth. Many reports have demonstrated that nutritional status profoundly affects circulating concentration of growth hormone (Blum et al. 1985; Breier et al. 1986; Ellenberger et al. 1989; Breier 1991). Insulin is known to be responsible for catabolic processes such as fat mobilisation and reduced protein accretion (Gregory et al. 1982; Blum et al. 1985). Thyroxin and tri-iodothyronine, hormones of the thyroid gland, are major regulators of metabolic rate, growth and development of animals (Kahl and Bitman 1983). However,

information on hormonal profiles in relation to yak' growth is very limited in the literature. This study attempted to identify seasonal changes in plasma concentrations of GH, insulin, T₃ and T₄ in growing yak at different ages under natural grazing conditions.

Material and methods

Ecological condition

Experimental yak were located at the Datong Yak Breeding Farm of Qinghai Province at an altitude of 3500–4800 metres above sea level (masl), with average annual precipitation of 463.2 to 636.1 mm, annual mean ambient temperature of between 2 and 4°C and no absolutely frost-free period throughout the year. The growing period of natural herbage, which germinates in late May and starts to wither in September, is only about 130 days. Herbage consists of alpine and mountainous meadows and is divided into cold (November to May) and warm (June to October) season pastures.

Animals

A total of 60 healthy yak were allotted to three groups as follows:

- Group A (GA) 30 yak, 0.5–1.5 years old
- Group B (GB) 20 yak, 1.5–2.5 years old and
- Group C (GC) 10 yak, 2.5–3.5 years old.

Each group had equal numbers of males and females. The animals were herded all year round and no pen or supplementary feeds were available in winter. Blood samples, grass samples and bodyweight measurements were performed at two-month intervals from September 1997 to July 1998.

Sampling

Blood samples were obtained from each yak before grazing in the morning. The samples were placed in tubes at room temperature for 3–4 hours until clotting and then centrifuged at 2000×g for 20 minutes to separate serum. The serum was stored at –20°C until assay. Yak bodyweight was determined with platform scale. On the grassland, five plots of 1 m² grassland were randomly selected and harvested. Grass samples were dried naturally at room temperature and placed in plastic bags until assay.

Laboratory analyses

GH, T₄, T₃ and insulin were measured by radio-immunoassay. Dry matter (DM), crude Protein (CP), minerals (M), crude lipid (CL), crude fibre (CF) and total energy (TE) in the grass samples were measured by conventional analyses.

Statistical analysis

Statistical analysis was conducted by SAS software and all the results were expressed in mean \pm SE. The data were analysed by PROC ANOVA using multiple comparisons for seasonal hormone changes in growing yak at different ages. The correlation analysis was done with a view to estimating correlations between blood hormones and bodyweight in growing yak.

Results

Seasonal hormone changes

The seasonal changes in hormones are presented in Table 1. GH had three peaks occurring in January, May and September, with a maximum value being in January (3.58 $\mu\text{g/L}$) and minimum value in March (1.52 $\mu\text{g/L}$). Only the differences among seasons in GA were significant ($P < 0.05$). No differences existed among groups in the same season ($P > 0.05$). The results show that GH concentration in yak is hardly affected by age, but is mainly affected by nutrition.

Average insulin concentration peaked in September (8.63 IU/mL) and was lowest in March (5.37 IU/mL). It varied significantly ($P < 0.01$) in GA and GB among seasons, being higher in July and September in both GA and GB than in other months, but lower in March in GA and in November in GB than in other months ($P < 0.05$). Within the same seasons there were significant ($P < 0.01$) differences among the three groups, being higher in GA than in GB and GC in both September and November.

The changes in T_3 and T_4 concentrations were basically consistent. T_3 concentration had its highest value in July (2.68 $\mu\text{g/L}$) and lowest value in May (0.60 $\mu\text{g/L}$). Within the same season, T_3 concentration in GA was significantly higher than those in the other two groups in March and November ($P < 0.05$). T_4 concentration had the highest value in September (62.56 $\mu\text{g/L}$) and the lowest value in November (28.32 $\mu\text{g/L}$). There were significant differences among seasons in the three groups ($P < 0.05$). T_4 concentration was higher in July in GA ($P < 0.05$), in July and September in GB, but was lower in March and November than in other months ($P < 0.05$). In GC, T_4 concentration was higher in September but lower in March and November than in other months ($P < 0.05$). In addition, there were significant differences between the three groups in September; T_4 concentration in GA being lower than those in GB and GC ($P < 0.05$).

Seasonal bodyweight changes

Yak bodyweight showed a clear seasonal pattern (Table 2). From September to November, the daily bodyweight gains of three groups exceeded 300 g, and from January to May there was a gradual bodyweight loss. From March to May, the daily bodyweight loss was around 220 g, but from May to July, there was a rapid bodyweight gain at 500 g per day (Table 3). In GA there was an unexpected daily bodyweight gain of 140 g from November to January at a

time when yak expected to go through a period of weight loss. This may have resulted from the fact that the animals were young (pre-weaning) and at the stage of high intensity of growth. Variance analysis shows that the changes in bodyweight of the three groups were significant ($P < 0.01$).

Table 1. Hormonal change of yak in different seasons.

Hormones	Month	Change in groups		
		GA	GB	GC
Growth hormone ($\mu\text{g/L}$)	January	3.82 ± 0.31	3.43 ± 0.13	3.84 ± 0.12
	March	1.07 ± 0.15	1.79 ± 0.32	1.71 ± 0.46
	May	2.27 ± 0.29	3.54 ± 0.24	3.17 ± 0.21
	July	2.04 ± 0.54	1.57 ± 0.22	2.39 ± 0.13
	September	2.58 ± 0.65	2.36 ± 0.35	3.41 ± 0.22
	November	2.38 ± 0.33	1.51 ± 0.44	1.84 ± 0.23
Insulin (IU/mL)	January	6.0 ± 2.1	6.1 ± 3.6	6.7 ± 3.4
	March	4.6 ± 1.8	5.0 ± 4.8	6.5 ± 5.2
	May	6.4 ± 2.8	6.1 ± 2.9	6.0 ± 2.2
	July	7.8 ± 3.4	7.7 ± 3.7	7.8 ± 3.0
	September	11.1 ± 2.0	8.3 ± 4.2	6.5 ± 2.8
	November	6.8 ± 0.8	4.2 ± 4.2	4.4 ± 4.8
T3 ($\mu\text{g/L}$)	January	0.56 ± 0.47	0.74 ± 0.31	0.94 ± 0.19
	March	1.56 ± 0.21	1.09 ± 0.18	1.17 ± 0.38
	May	0.7 ± 0.23	0.56 ± 0.37	0.54 ± 0.32
	July	1.67 ± 0.42	2.47 ± 0.29	2.90 ± 0.22
	September	2.58 ± 0.28	2.36 ± 0.48	2.21 ± 0.41
	November	1.77 ± 0.51	1.29 ± 0.18	1.14 ± 0.49
T4 ($\mu\text{g/L}$)	January	40.38 ± 18	47.38 ± 14	45.25 ± 18
	March	36.24 ± 15	32.00 ± 15	28.10 ± 16
	May	47.29 ± 19	53.37 ± 14	51.85 ± 18
	July	63.84 ± 14	61.64 ± 12	57.93 ± 10
	September	43.85 ± 19	71.68 ± 13	72.15 ± 13
	November	32.79 ± 9	24.47 ± 8	27.69 ± 10

Table 2. Bodyweight change of yak (kg).

Month	Bodyweight of three groups		
	GA	GB	GC
September	59.39 ± 16.78	126.52 ± 10.33	151.37 ± 11.05
November	89.94 ± 12.28	149.75 ± 14.36	171.17 ± 10.11
January	98.21 ± 15.32	146.59 ± 12.75	168.33 ± 18.61
March	95.78 ± 11.88	140.10 ± 9.54	157.72 ± 10.93
May	84.72 ± 14.29	129.11 ± 9.86	143.01 ± 12.97
July	115.81 ± 14.60	159.14 ± 10.54	179.32 ± 15.48

Table 3. Daily bodyweight change of yak (g).

Periods	Daily bodyweight gain		
	GA	GB	GC
25 September–25 November	500.82	387.55	330
26 November–24 January	140.17	-52.17	-47.33
25 January–26 March	-41.90	-108.19	-176.83
27 March–23 May	-184.33	-183.17	-245.17
24 May–26 July	518.16	500.5	605.17

Grass yield and nutritional composition

Grass yields increased gradually from May to July and stabilised from July to September, then began to decline, dropping to the lowest level in May of the following year (Table 4). Crude protein (CP) content fluctuated between seasons, with a maximum value of 12.92% in July and a minimum value of 5.47% in March. CL declined from 3.56% in September to 1.28% the following May. In contrast, CF had the lowest value of 16.5% in July and the highest value of 27.52% in November. TE, CL and CP were consistent and showed a single-peak with the highest values from July to September and the lowest values the following May. The period of the highest yield and quality for the grass was from July to September in the Datong Yak Breeding Farm, the yield and quality of grass declining gradually from November to May.

Table 4. Yield and nutrients of herbage.

Items	January	March	May	July	September	November
Yield (kg/m ²)	34.91	27.42	22.25	74.27	64.56	57.02
CL (%)	1.93	1.71	1.28	2.52	3.56	2.39
CF (%)	24.42	24.61	22.54	16.5	24.06	27.52
CP (%)	5.51	5.47	8.37	12.92	9.28	6.02
DM (%)	90.85	90.12	89.86	90.69	89.92	90.96
M (%)	11.55	13.82	13.45	19.78	7.12	6.2
TE (MJ/g)	1.70	1.68	1.67	1.77	1.78	1.76

CL= crude lipid; CF= crude fibre; CP= crude protein; DM= dry matter; M= minerals; TE= total energy.

Correlation of bodyweight and hormones

Table 5 showed the correlations between bodyweight and hormones. Among the hormones studied, T₄ concentration had a significantly positive correlation with bodyweight ($r = 0.2509$, $P < 0.01$), but the correlation of T₃ and GH concentrations were not significant ($P > 0.05$). Insulin concentration had very marked positive correlations with T₃ and T₄ concentrations ($P < 0.01$). T₃ and T₄ concentrations were also significant ($P < 0.01$).

Table 5. correlation matrix of hormones and bodyweights.

	Body weight	T ₃	T ₄	Insulin	Growth hormone (GH)
Bodyweight	1	0.0673	0.2509**	-0.0510	0.0075
T ₃		1	0.2886**	0.2950**	-0.0547
T ₄			1	0.3235**	0.0218
Insulin				1	0.0555
Growth hormone (GH)					1

** = Values show ray significant correlations

Discussion

The bodyweight of yak increased mainly from May to November and the absolute bodyweight gain was highest from May to September when the daily bodyweight gain of two or three year-old yak was 500 to 600 g (Table 3). Daily bodyweight gain was 300 to 400 g from September to November, although grass on pasture gradually became withered. The bodyweight of one-year-old yak continued to increase from November to January, mainly because these animals were not entirely weaned. The bodyweight declined from November to next May and the bodyweight loss was most severe with daily weight loss of 180 to 250 g from November to the following May, the bodyweight loss gradually increasing because grass reserve reduced gradually.

Circling GH was elevated in January and May when both grass production and nutritive value was the lowest, and then decreased in July when grass growth was at high peak. There are many reports of an elevation in the concentration of GH in cattle during restricted feeding (Blum et al. 1985; Breier et al. 1986; Breier et al 1988; Ellenberger et al. 1989). An increase in the half-life of GH in the circulation of cattle influenced the increase in GH during restricted feeding (Trenkle 1976). Furthermore, enhanced levels of GH seem to result from an increase in amplitude vs. frequency of the pulse of GH (Breier et al. 1986; Ellenberger et al. 1989). In the current study, the mean concentration of GH declined when grass was sufficient, which is in agreement with other results (Blum et al. 1985; Hayden et al. 1993). Although circulating levels of GH decreases as an animal matures (Trenkle 1977), a concomitant increase in the quantity of GH binding sites in peripheral tissues has been suggested to maintain GH action (Breier et al. 1991). In addition, during re-feeding, enhanced growth rates and transient increases of nitrogen balance were not associated with a corresponding rise in GH levels. Thus, under certain conditions, circulating levels of GH do not correlate with growth (Joakimsen and Blom 1976; Trenkle 1977; Blum et al. 1985). This is also in agreement with the result of the present study. But in the current study, the results in March and September were not in agreement with previous reports, mainly due to the difference between yak and cattle. As yak inhabits the remote mountains, a major proportion of the variation observed in the present study may have been due to other factors, such as, ambient temperature, seasonal photoperiodism, sampling variances and

genetics. As many factors are involved in the regulation of GH secretion, it is necessary to conduct more systematic studies to better understand the GH patterns in the yak.

Insulin levels showed clear seasonal patterns with grass production and composition. In July and September when grass was sufficient insulin concentrations of growing yak reached maximum. In contrast, in March and May when grass was inadequate insulin concentration declined to a minimum. According to Blum et al. (1985), in steers, the levels of circulating insulin declines during periods of food restriction. It probably facilitates catabolic processes such as fat mobilisation and is presumably responsible for reduced protein accretion. The increase of circulating insulin during re-feeding was possibly related to enhanced fat deposition. This also is in agreement with recent reports in cattle (Hayden et al. 1993).

T₄ concentration decreased during nutritional deficiency and increased during nutritional sufficiency in growing yak of different ages. A similar reduction in plasma T₄ concentration was reported in other studies involving feed-restricted cattle (Blum et al. 1985; Ellenberger et al. 1989; Hayden et al. 1993) and sheep (Blum et al. 1980). T₃ concentration showed basically identical pattern, but from the whole change, the level of T₄ varied more than did that of T₃. However, T₃ level has been reported to be more closely associated with shifts in energy status in cattle (Blum et al. 1985). Kahl (1978) reported that T₃ increased faster than T₄ both in male and female Holstein cattle. The present result agrees with the observations suggesting that T₃ should be considered the main biologically active thyroid hormone and that T₄ must be converted to T₃ before its activity is exerted (Kahl et al. 1983). In addition, the positive correlation between T₃ and T₄ in our study indicated that the increase of T₄ level in May was a transient rise during the process of the conversion of T₄ to T₃.

Kahl (1978) reported that the positive correlation of thyroid hormone with bodyweight in the Holstein cattle was in accordance with relationships described during normal growth of cattle (Blum et al. 1980; Kahl et al. 1983). Our result indicated that T₄ concentration in growing yak was significantly positively correlated with body weight, and that T₃ concentration was not correlated with bodyweight. This result is also consistent with results from other studies (Rumsey 1981; Verde and Trenkle 1982) that only the T₄ concentration had marked positive correlation with bodyweight gain.

In conclusion, the bodyweight of growing yak increased in warm season and decreased in cold season. This was attributed to seasonal changes in available grass. The seasonal changes in hormones coincided basically with that of the grass grazed, and the T₄ concentration was positively correlated with bodyweight in growing yak. Therefore, T₄ level could be used to define and evaluate nutritional condition of yak that are more than two years old to determine optimum time for supplemental feeding to prevent loss of bodyweight in the cold season.

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Physiological responses of yak under different environments

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Summary

Adaptability of seven healthy adult female yak ranging in age from 3.5–4 years and weighing 200–250 kg, raised on the farm premises of the National Research Centre on Yak, India, at an altitude of 2730 metres above sea level (masl), was assessed in terms of selected physiological parameters—rectal temperature, pulse rate, respiratory rate and water intake, and level of blood metabolites—glucose and volatile fatty acids (VFA)—during cold humid and moderately cold humid seasons as identifiable in this zone. Rectal temperature, pulse rate and respiratory rate were significantly higher in moderately cold humid season than in cold humid season whereas blood glucose and VFA levels were higher in cold humid season than in the other season. The Dairy Search Index was found to be 0.95 and 1.24 in cold humid and moderately cold humid seasons, respectively. It was apparent from the comparative picture of physiological responses in yak during these two seasons that the animals suffered from considerable heat stress during moderately cold humid season. The common husbandry practice of the yak farmers is that during summer months (moderately cold humid) they take their yak to higher altitudes (4500–6000 masl) and during winter months (cold humid) they move down to approximately 3000 masl so that their yak live on approximately same weather conditions. The present study presents scientific explanation for the up and down migration of the yak herders during summer and winter months.

Keywords: Yak, adaptability, dairy search index, thermoregulation

Introduction

The adaptability of an animal to the environmental conditions in which it is to be maintained greatly influences its production efficiency. Lack of adaptability of yak, especially to heat, has been an important limiting factor in their large-scale introduction in the tropics. Evaluation of physiological responses of yak under different geo-climatic conditions, is therefore an essential pre-requisite in formulating suitable breeding plan. The present investigation, the first of its kind in our opinion, deals with the evaluation of physiological responses of yak under different environments.

Materials and methods

Experimental animals comprised seven healthy adult female yak, 3.5–4 years of age and weighing 200–250 kg, raised on the farm premises of the National Research Centre on Yak, India, at an altitude of 2730 masl and maintained on a combination of both grazing and concentrate supplement. The study was conducted for 10 days each during cold humid (season 1) and moderately cold humid seasons (season 2) as identifiable in this zone. The meteorological attributes during the two seasons are presented in Table 1.

Table 1. Meteorological attributes during of the two seasons of the study (mean \pm SE).

Season	Mean daily temperature (°C)	Mean daily relative humidity (%)
Cold humid	4.7 \pm 2.3	74.5 \pm 3.9
Moderately cold humid	18.1 \pm 0.3	74.2 \pm 2.5

Rectal temperature, respiration rate and pulse rate of the animals were recorded at 07:00 and 15:30 h daily. Rectal temperature was recorded by putting a clinical thermometer in the rectum for 1 min., respiration rate with the help of a stethoscope and pulse by placing a fingertip on the coccygeal artery with minimum disturbance of the animal. The morning observations were taken before offering any feed and water. In the afternoon, the observations were recorded about 30 minutes following return from grazing to eliminate the effect of grazing activity. Water was offered *ad libitum* at 10:00 and 14:00 h and the individual intakes recorded. The water intake per 100 kg body weight was calculated. Blood samples from each animal were also taken daily at 07:00 and 15:00 h for the determination of glucose (Webster et al. 1971) and total volatile fatty acids (VFA) (Gupta et al. 1988). From the data, Dairy search indicis (DSI) (Bonsma 1949) were determined from the following equation:

$$DSI = 0.5 \times x_1/x + 0.2 \times y_1/y + 0.3 \times z_1/z,$$

where x_1 , y_1 and z_1 are the observed rectal temperature (°C), respiration rate and pulse rate, respectively. x , y and z are normal (expected) rectal temperature, respiration rate and pulse rate, that is 38.33°C, 23/min. and 60/min, respectively. Average of each response for each season was calculated for each animal and used for further statistical analysis (Snedecor and Cochran 1967) (Table 2).

Table 2. Analysis of variance of respiratory frequency, rectal temperature, pulse rate, water intake, dairy search index, VFA and glucose.

Sources of variation	d.f.	Respiratory frequency		Rectal temperature		Pulse rate		Water intake		Dairy search index		Glucose		VFA	
		MSS	F	MSS	F	MSS	F	MSS	F	MSS	F	MSS	F	MSS	F
Season	1	2540.3	74.4*	5.7	31.8*	768.8	44.3*	20.2	38.2*	0.41	94.06*	3508.60	339.70*	2628.90	218.90*
Error	18	34.1		0.18		17.3		0.53		0.004		10.3		12.0	
Total	19														

* = $P < 0.01$.

Results and discussion

The average physiological responses in two seasons are presented in Table 3.

Table 3. Average physiological responses of yak during the two seasons.¹

Parameters	Cold humid season	Moderately cold humid season
Respiratory frequency/min.	15.0–24.2 (20.0 ± 1.2)	32.3–58.3 (42.5 ± 2.3)
Pulse rate/min.	51.6–60.9 (56.8 ± 0.9)	63.1–78.2 (69.2 ± 1.6)
Rectal temperature (°C)	100.8–102.1 (101.3 ± 0.1)	101.8–103.5 (102.4 ± 0.1)
Water intake (L/100 kg body weight/day)	5.2–7.8 (6.6 ± 0.2)	7.3–9.8 (8.6 ± 0.2)
Blood glucose (mg/100 mL)	35.6–47.9 (41.9 ± 1.2)	11.8–19.1 (15.5 ± 0.7)
Blood VFA (mmoL/L)	68.4–77.1 (73.7 ± 0.8)	42.2–57.8 (50.7 ± 1.3)
Dairy search index	0.89–0.99 (0.95 ± 0.01)	1.1–1.4 (1.2 ± 0.02)

1. Figures in the parenthesis give the mean ± SE.

Respiratory frequency

The respiratory frequency was significantly ($P < 0.01$) higher in season 2 (18.1°C) than in season 1. The respiratory frequency has been reported to increase significantly around 20°C in the European breeds of cattle and around 32°C in Brahman cattle, although it starts rising around 16–18°C and 28°C, respectively (Kibler and Brody 1949, 1950, 1951). At higher temperature, the peripheral warm receptors in the skin become activated and send neural signals to the warm receptors located in the anterior hypothalamus in order to trigger the respiratory activity to increase the rate of heat loss from the body (Hafez 1968).

Rectal temperature

The rectal temperature in all the animals rose significantly ($P < 0.01$) higher during season 2 than that in season 1. Significant rise in the rectal temperature at 27.3°C ambient temperature has been reported in cattle (Singh 1977), and in goats and sheep (Ghosh and Pan 1994). Any imbalance in the ratio of heat production to heat loss, which cannot be manoeuvred by the different thermoregulatory mechanisms, is reflected by the increase in body temperature.

Pulse rate

The pulse rate increased significantly ($P < 0.01$) higher in season 2 in comparison to that in season 1. An increase in pulse rate at higher temperature has been reported in cattle (Worstell and Brody 1953; Beakley and Findlay 1955; Bianca and Findlay 1962; Whittow 1971). In hyperthermia due to severe heat stress, Whittow (1971) observed an increase in the heart rate, which he attributed to the Van Hoff Arrhenius effect.

Water intake

The water intake (per 100kg body weight/day) was significantly ($P<0.01$) higher during season 2 than that in season 1. The evaporative loss of water in hot environment is expected to be more than that in a cool environment (Thompson et al. 1949, 1951) and an increase in water intake under higher temperature stress has been reported in cattle (Horrochs and Philips 1961; McDowell et al. 1969; Saxena 1976).

Glucose and VFA level

The blood glucose and VFA levels were significantly ($P<0.01$) higher during season 1 in comparison to that in season 2. The decrease in sugar and VFA level on heat exposure has also been reported in cattle (Riek and Lee 1948) and in sheep and goats (Ghosh and Pan 1994). Cold exposure increases blood glucose level in ruminants due to the increase in circulating thyroid and adrenal hormones and this contributes to metabolic heat production (Weeks et al. 1983).

Dairy search index (DSI)

The DSI during season 1 was 0.95 whereas in season 2 it was significantly ($P<0.01$) higher (1.24). Much deviation of the index from '1' indicates the decrease in thermal adaptability.

It is apparent from the comparative picture of physiological responses in yak during the two seasons that the animals suffered from considerable heat stress during moderately cold humid season. The natural habitat of yak starts from 3000 masl. The common husbandry practice of the yak farmers is that during summer months (moderately cold humid) they take their yak to higher altitudes (4500–6000 masl) and during winter months (cold humid) they move them down to approximately 3000 masl so that the animals live on approximately same environmental conditions. The present study provides scientific explanation to the up and down migration of the yak herders during summer and winter months.

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Productivity of yak in southern Qinghai Province

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Introduction

Southern Qinghai is the main habitat of Qinghai yak. This study was conducted to evaluate the growth, development, meat and milk production of the local yak to provide information as a basis for the genetic improvement of yak in the area.

Materials and methods

Milk productivity of Guoluo yak

Ten yak cows were divided into two groups: a group of 5 cows, which were in their second lactation; and another group of 5, which were in their first lactation. The milk yield was determined from May to September with milking once a day in May and September and twice a day for the other months.

Effect of nursing state on growth and development of female yak

Seven yak cows with calves and 5 without calves were ear-tagged and weighed on 10 May 1997, 7 November 1997, 15 March 1998 and 7 June 1998.

Meat productivity of Guoluo yak

Six pack animals, consisting of three in advanced age (more than 10 years) and three younger sets (5-7 years of age), were selected from the Xueshan Township for a slaughter experiment on 27 and 28 September 1998.

Results and discussion

Growth and development of local yak

Local yak, ranging in age from birth to 5 years, were weighed at an interval of 6 months (Table 1). The results showed a rapid growth before 2.5 years. The following years showed little variation until the age of 4. From 4 years on, the body weight varied substantially with seasons. However, the average body weight obtained from this study was lower than the previous investigation in the early 1980's, which indicated degeneration in the performance of the local yak.

Table 1. Body weight (kg) and linear body measurements (cm) of Guoluo yak.

Age (year)	Body weight	Height	Body length	Heart girth	Cannon bone circumference
At birth	11.74 ± 1.27	52.60	48.45	56.38	7.71
0.5	50.18 ± 10.74	79.60	76.77	96.47	10.75
1	83.01 ± 12.89	87.46	90.72	121.19	13.86
1.5	99.42 ± 16.31	89.10	91.35	115.00	12.63
2	109.68 ± 16.63				
2.5	134.10 ± 27.77				
3	135.23 ± 18.59				
3.5	141.31 ± 40.71				
4	143.89 ± 25.74				
4.5	196.68 ± 21.27				
5	156.42 ± 30.33				

Milk productivity of the local yak

The data on milk production showed a higher milk yield in cows (1.06 kg) than in the heifers (0.67 kg). However, for both groups (cows and heifers), milk yield was higher in June, July and August than in May and September. Milk fat was 6.57% for cows and 6.69% for heifers.

Effect of nursing state on growth and development of the female yak

The body weight of cows in nursing and non-nursing states increased by 3.4 kg (about 2%) and 13.65 kg (7.7%), respectively. The non-nursing cows showed an obvious increase in body weight from later spring to autumn in 1997 but a rapid decrease from the autumn of 1997 to the next spring in 1998 (Table 2).

Table 2. *Body weight of cows at different nursing states.*

Nursing state	10 May 1997	7 Nov. 1997	15 March 1998	7 June 1998
Nursing	166.8 ± 27.5	185.7 ± 33.2	172.7 ± 32.2	170.2 ± 19.2
Non-nursing	178.1 ± 17.5	243.2 ± 20.6	222.0 ± 13.3	191.8 ± 11.7

Meat productivity of the local yak

Results from the slaughter test indicated that the older yak (over 10 years) were heavier, had a higher dressing weight, produced a higher net meat yield, had heavier bone and a larger eye muscle area than the younger (5–7 year old) animals (Table 3).

Table 3. *Meat production of the local yak.*

Age (year)	Live weight (kg)	Dressed weight (kg)	Net meat (kg)	Bone (kg)	Eye muscle area (cm ²)
>10	373.3 ± 25.2	210.3 ± 24.7	176.4 ± 24.8	33.9 ± 2.3	53.2 ± 9.4
5–7	203.3 ± 27.5	110.8 ± 25.5	90.6 ± 25.3	20.1 ± 7.0	41.4 ± 10.8

Due to the lower meat and milk productivities of the local yak, it was suggested that crossbreeding by introducing wild yak genetics should be considered as a possible approach for their improvement.

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Ecological and physio-biochemical parameters of yak in highland conditions of Kyrgyzstan

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Introduction

Kyrgyzstan is a mountainous country completely located in a zone of central Tian-Shan. Mountain ranges extend from east to west direction and have heights from 3000 up to 7000 metres above sea level (masl). The mountains are covered with large fields of various meadows, pastures, hay fields, woods, and are inexhaustible sources of medicinal plants, minerals, and representatives of unique kinds of wild fauna. The huge areas of natural pastures and haymaking are distributed as follows: 48% in mountains, 30% in high-mountainous areas, 17% in foothills, and 5% in agricultural valleys. About 52% of grazing fodder comes from spring and autumn pasture, 22% from winter and 26% from summer meadows. However, animals consume only 64% of the total usable natural fodder land in the republic. Thus, there is a huge potential for the development of yak in the republic. Yak production is practically restricted to farms located in mountain and high-mountainous regions.

The transition of the Republic to a market economy and the reform of agricultural sector is a welcome change. There was a sharp reduction in livestock production. Huge pastures and haymaking areas remained unutilised for a long time. Some valuable livestock breeds created through long-term efforts by scientists have completely disappeared. Examples include Tian-Shan sheep, a fine and rough wool breed; the breed of new Kyrgyz horse; the breed of Kyrgyz chicken; and highly productive duck breed; several breeds of pigs; and the Alatau large horned cattle. The population of yak has also decreased by almost 3 times. Certainly, the local farmers kept some animals, but because of the absence of systematic selective breeding effort for their improvement, they have lost important qualities.

The development of yak breeding in Kyrgyzstan, in our opinion, is a high priority activity. The yak are year round forage users, grazing on pastures located at altitudes ranging from 3500 up to 4500 masl. It has been reported that during winter, the loss in live weight for the large horned cattle is in the order of 27.5% and 22–28% for sheep, but only 16.1% for yak.

Despite such advantages of yak breeding, yak breeding and development has not received the level of attention that it deserves. In particular, no study has been done on the physiological and biochemical bases of yak' productivity in the severe mountain conditions of Kyrgyzstan. There is a need to develop theoretical bases to increase the efficiency of yak production. In addition, the botanical and chemical composition of the forage used by yak

in different seasons of the year must, in a certain way, relate to the digestive processes in the yak and, in turn, the efficiency with which the animals use these feeds.

Therefore, the study of yak digestive processes, in particular the rumen, in different seasons of the year under natural grazing conditions may provide vital information about metabolism utilisation of the nutrients in these forages, which can subsequently facilitate the development of improved feeding strategies that increase efficiency of utilisation of these feeds.

Materials and methods

The study was conducted at the collective farm of Talas, at an altitude of 3000–4000 masl. Three female yak aged 5 years and weighing 275–280 kg were used. All animals were fitted with rumen fistula and were grazed on natural pasture year round. The following constituted the focus of the study:

1. Chemical structures of forages eaten by yak;
2. pH, number of infusorium, protein, carbon and mineral exchanges in rumen, cellulolytic and proteolytic activity of the rumen liquid; and
3. Dependence of yak live weights on nutrition value of the pastures and rumen metabolism level in different seasons of the year.

Results and discussion

Chemical contents of edible forages

The high mountain forages were sampled from the top ranges of the mountains (Table 1). The highest water content of forages was observed in the spring, but this decreased in the subsequent seasons of the year, reaching a minimum in winter. The highest crude protein level was recorded in summer, and lowest in winter. The highest crude fat content was in autumn and the lowest in winter. Crude fibre was highest in winter and lowest in spring.

Table 1. *Chemical contents of highland pasture in different seasons of year (% DM).*

Season	Water	Crude protein	Crude fat	Crude fibre	Nitrogen-free extracts
Spring	76.14	14.67	4.35	29.13	42.07
Summer	68.31	17.41	4.15	33.40	33.80
Autumn	35.24	10.31	5.77	34.63	39.57
Winter	24.61	4.66	3.39	36.69	46.39

There was a marked seasonal variation in mineral content of forages (Table 2). Calcium increased in the autumn, reaching a maximum then decreasing to a minimum in winter. The highest level of phosphorus was in spring forages, but it gradually decreased, reaching a

minimum in winter forages. Sodium and potassium levels changed in similar pattern to that of phosphorus. However, the reduction in sodium content was less dramatic than that of potassium. The most favourable ratio of calcium and phosphorus was observed in spring and summer forages, but the ratio became undesirable in the winter and autumn seasons because of the high calcium contents. The relationship between calcium and sodium was less than optimum throughout the year, although in winter and autumn it was more or less favourable. The results showed that the forages were generally poor throughout the year. In general, the forages in spring and summer were more nutritive than those in autumn and winter.

Table 2. Mineral contents in pasture in different seasons of year (g/kg DM).

Season	Calcium (Ca)	Phosphorus (P)	P:Ca	Sodium (Na)	Potassium (K)	Na:K
Spring	7.20	2.97	1:2.4	0.32	21.6	1:66.5
Summer	5.36	2.18	1:2.4	0.30	19.26	1:63.4
Autumn	8.88	1.44	1:6.2	0.29	5.28	1:17.9
Winter	4.32	0.64	1:6.7	0.27	3.41	1:12.5

Physiology of rumen digestion

The characteristics of the rumen environment depended on the season (Table 3). The average pH in spring and summer was the same (6.75). Daily pH ranged from 6.62 to 6.87 in spring and 6.57 to 7.00 in summer. The pH increased from autumn to winter, with a daily fluctuation of 6.18 to 7.44 in autumn and 6.98 to 7.22 in winter.

Table 3. Physiological parameters in yak rumen at difference seasons.

Parameter	Season			
	Spring	Summer	Autumn	Winter
pH	6.8 ± 0.03	6.8 ± 0.40	6.9 ± 0.06	7.1 ± 0.03
Infusorium (10 ³ /mL)	276.0 ± 9.90	456.6 ± 12.6	305.0 ± 11.2	198.5 ± 7.2
Proteinase (%)	7.1 ± 0.31	7.2 ± 0.69	7.8 ± 0.61	6.4 ± 0.18
Cellulosase (%)	15.2 ± 0.60	18.7 ± 0.92	14.3 ± 0.78	9.9 ± 0.19
Total N (mg%)	113.0 ± 3.03	145.7 ± 2.48	139.7 ± 0.86	66.7 ± 1.63
Protein N (mg%)	51.5 ± 3.01	91.5 ± 3.31	85.2 ± 1.10	27.0 ± 1.72
Residual N (mg%)	61.5 ± 0.93	54.2 ± 2.15	54.3 ± 0.51	39.7 ± 1.54
Ammonia (mg%)	38.9 ± 1.00	49.8 ± 0.27	16.2 ± 0.47	11.1 ± 0.68
Total volatile fatty acids (mM%)	10.0 ± 0.32	10.7 ± 0.35	8.1 ± 0.19	6.2 ± 0.20
Acetic acid (%)	70.2 ± 1.24	78.1 ± 1.26	84.5 ± 0.74	76.5 ± 1.05
Propion acid (%)	14.3 ± 0.53	13.7 ± 0.85	10.8 ± 0.53	15.7 ± 0.63
Oil acid (%)	13.0 ± 0.63	7.2 ± 0.45	4.3 ± 0.29	7.0 ± 0.42
Ca (mg/L)	361.4 ± 6.73	474.8 ± 7.00	315.3 ± 6.73	220.4 ± 6.62
P (mg/L)	212.2 ± 4.53	263.4 ± 60.2	217.7 ± 5.28	198.0 ± 4.78
K (mg/L)	1057.7 ± 31.4	1161.5 ± 21.4	976.8 ± 33.4	476.2 ± 16.4
Na (mg/L)	1962.0 ± 14.0	2927.3 ± 13.0	1987.6 ± 15.5	1540.8 ± 13.4

The number of infusorium in yak rumen was also influenced by season-dependent physiological changes. The average number recovered ranged from the lowest ($276.0 \times 10^3/\text{mL}$) in spring, rising to the highest level in summer, before decreasing in autumn. The daily changes of the number were from 262.7 to $295.7 \times 10^3/\text{mL}$ in spring, from 414.3 to $499.3 \times 10^3/\text{mL}$ in summer, from 286.0 to $331.0 \times 10^3/\text{mL}$ in autumn, and from 194.5 to $230.7 \times 10^3/\text{mL}$ in winter.

In comparison with data from cattle, the pH value in yak rumen was relatively stable across seasons of the year but the number of infusorium was a little bit higher in summer and autumn but much lower in winter than that in the large horned cattle.

The fermentative activity of yak rumen was considerably influenced by season. The highest proteolytic and cellulolytic activities in the rumen fluid were observed in the spring, summer and autumn but the lowest in winter. All other parameters, including total nitrogen (N), protein N, residual N, ammonia, total volatile fatty acids (TVFA), Ca, P, K and Na relating with the rumen fermentation indicated similar seasonal patterns with those of the proteinases and cellulosases. Exceptions are summarised below:

1. The biggest fluctuation in total N was observed in spring from 91.6 to 125.7 mg%; there was much less fluctuation in other seasons. Compared to the situation in large horned cattle, the total N in yak was more in summer and autumn but less in winter.
2. The daily fluctuation in protein N was 35.9 to 63.6 mg% in spring, 83.7 to 101.1 mg% in summer, 76.6 to 90.4 mg% in autumn and 24.8 to 29.0 mg% in winter. Compared with the large horned cattle and sheep, the yak seem to have similar protein N in spring and autumn but higher protein N in summer and less protein N in winter (by 1.5 to 2.5 times).
3. The daily residual N changed from 57.4 to 65.6 mg% in spring, 48.2 to 59.9 mg% in summer, 52.0 to 57.2 mg% in autumn and 37.0 to 42.6 mg% in winter. Thus, highest variation of parameters of residual nitrogen within a single day was observed in the summer. Comparative analysis revealed that the yak had more residual N in spring, summer and autumn but a similar amount in winter compared with sheep. However, the large horned cattle have more residual N than yak in winter.
4. The daily fluctuations of ammonia ranged from 34.2 to 42.7 mg% in spring, 48.2 to 50.2 mg% in summer, 15.2 to 16.8 mg% in autumn and 10.0 to 12.4 mg% in winter. Compared to sheep and the large horned cattle, the yak have more ammonia in spring and summer than in sheep but similar levels to that in cattle.
5. The minimum daily TVFA was observed at 08:00 h and the maximum at 20:00 h. There was no difference between yak TVFA and that of sheep and large horned cattle in spring, summer and autumn. However, the yak TVFA were lower in winter.
6. The daily changes of acetic acid fluctuated from 66.4 to 71.4% in spring, 72.1 to 81.7% in summer, 82.6 to 86.5% in autumn and 75.2 to 78.0% in winter. The comparative data showed that the acetic acid levels in yak rumen in autumn, summer and winter were much higher than in the large horned cattle and sheep.
7. The daily propionic acid in yak rumen changed from 12.7% to 15.9% in spring, 11.4% to 18.1% in summer, 10.2% to 11.1% in autumn and 14.4% to 16.5% in winter. Further comparison indicated that the propionic acid levels in yak were lower in all

seasons than that in the large horned cattle and sheep, especially in autumn and summer (lower by 1.5 to 2.5 times).

8. The daily oil acid changed from 12.7 to 16.1% in spring, 5.3 to 8.6% in summer, 2.9 to 6.0% in autumn and 6.4 to 7.4% in winter. Comparing the oil acid levels in yak rumen with other animals, the possible conclusion was that the maximal concentration in yak in spring corresponded to the minimal value of the large horned cattle and sheep, but the daily average concentration of the oil acid in yak rumen in other seasons was lower than that in sheep and large horned cattle.
9. The Ca contents in yak rumen were much lower than for other animal species.
10. The concentration of P was influenced by season. In spring, in spite of the fact that the forages may supply much more P than in other seasons, the P in yak rumen was lower than that in summer or autumn. The daily P value changed from 190.7 to 223.2 mg/L in spring, 230.1 to 318.3 mg/L in summer, 206.5 to 226.0 mg/L in autumn and 181.6 to 212.3 mg/L in winter. The minimal concentration in all seasons of the year was marked in the morning hours and maximal at night. The P contents in yak rumen were much lower than that in the large horned cattle and sheep, but the fluctuations were smaller.
11. The K concentrations in yak rumen in spring, summer and autumn seasons were lower by 2 times, and in winter by 4 to 5 times than that in sheep and large horned cattle.
12. The Na contents in yak rumen corresponded to that in other animal species.

Live weight of yak

There were differences between seasons in yak live weights. The highest live weight was observed in the summer with an average of 284.0 ± 14.2 kg. This was followed by a decrease to 278.8 ± 3.78 kg in autumn and down to 246.2 ± 1.84 kg in spring and finally to the lowest of 240.5 ± 3.10 kg in winter. Thus, the greatest weight loss was from middle of October to the end of April.

Recommendations

Unlike the large horned cattle, which usually breed the year round, the oestrus of yak occurs only from July to August and the gestation period averages 257 days. Hence, the calving time is around March to April. Therefore, it is necessary to supplement in-calf animals in this period, especially in last three months of pregnancy. We recommend that a supplement of 3 kg of mountain hay and 2 kg of straw/animal per day.

Insulin, prolactin and growth hormone concentrations in yak colostrum and milk

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Summary

Insulin, prolactin and growth hormone concentrations in yak colostrum and milk were analysed by radio-immunoassay (RIA) method. Colostrum from day 1 of lactation contained the highest concentrations of the three hormones compared with the colostrum from day 2 to 7 of lactation and the milk from early lactation. Except growth hormone, concentrations of both insulin and prolactin in colostrum were significantly higher than concentrations in milk of early lactation. There were significant differences among individuals in the concentrations of the three hormones in colostrum.

Keywords: Colostrum, growth hormone, insulin, prolactin, yak

Introduction

Hormones in milk are related functionally to the development, growth and secretion of mammary gland (Wang and Zou 1995). Most hormones in milk are uptakes from plasma by mammary gland. Colostrum usually contains higher levels of hormones than does plasma and milk and the intakes of these hormones via colostrum have been proven to play an important role in metabolism and growth of newborn offspring (Lorraine et al. 1986). However, there is limited information on hormones in yak milk. What is available is confined only to reproductive hormones in colostrum and milk (Wei et al. 1990; Yu et al. 1993). The objective of this study was to investigate the dynamic changes of insulin, prolactin, and growth hormone in colostrum from the first week after parturition.

Materials and methods

All samples were obtained from Longri breeding stock farm in Sichuan Province, P.R. China. Colostrum samples were collected daily from six Maiwa yak in the first week after parturition. Approximately 50 mL of colostrum were obtained from each yak by manual milking in the morning. A total of 28 milk samples from early lactation (from 20 to 40 days after parturition) were collected as control. Five samples of plasma were collected from

lactating yak cows at the same stage of lactation for prolactin analysis. All samples were stored at -20°C .

Skimmed milk was obtained by separating fat from whole milk under centrifugation for 20 min at 4°C . Insulin, prolactin and growth hormone concentrations in the skimmed colostrum and milk were assayed by radio-immunoassay (RIA) method. RIA kits for human insulin and growth hormone were obtained from Shanghai Biological Product Institute, and RIA kits for human prolactin were obtained from Tianjin Depu Biotechnology and Medical Product Company Ltd. Bovine growth hormone concentration (Y) was calculated as: $Y = (X - 0.2926)/0.019$, where X was the value detected with RIA kit for human growth hormone.

Results and discussion

The highest levels of insulin, prolactin and growth hormone were observed in colostrum from day 1 of lactation, with big variations among individuals (Table 1). Insulin concentration in day 1 colostrum ranged from $86.49 \mu\text{u/mL}$ to $1335.84 \mu\text{u/mL}$, prolactin from 4.80 ng/mL to 183.23 ng/mL , and growth hormone from 66.71 ng/mL to 2366.71 ng/mL . These hormones declined sharply within one or two days after parturition. Concentrations of both insulin and prolactin in colostrum were consistently significantly higher than that in the milk from early lactation, while the growth hormone was significantly higher only in colostrum from day 1 of lactation relative to that in the milk from early lactation. Milk prolactin level was similar to that of plasma of lactating yak (0.49 ± 0.43 , $n = 5$).

Table 1. Hormone concentrations in yak colostrum and milk.

Samples	Days of lactation	Insulin ($\mu\text{u/mL}$)	Prolactin (ng/mL)	Growth hormone (ng/mL)
Colostrum	1	$457.26 \pm 412.97^{**}$	$43.39 \pm 63.97^*$	$456.88 \pm 854.49^*$
	2	$446.96 \pm 549.23^{**}$	$2.05 \pm 0.66^{**}$	53.11 ± 8.84
	3	$85.09 \pm 05.35^{**}$	$1.73 \pm 0.60^{**}$	54.77 ± 7.08
	4	$58.27 \pm 7.58^{**}$	$2.14 \pm 0.93^{**}$	51.53 ± 9.80
	5	$40.22 \pm 14.74^{**}$	$1.41 \pm 0.76^{**}$	49.95 ± 12.53
	6	$37.42 \pm 9.87^*$	$1.13 \pm 0.33^{**}$	56.33 ± 9.00
	7	27.65 ± 5.91	$1.15 \pm 0.46^*$	52.58 ± 13.57
Milk	20-40	25.58 ± 9.80	0.31 ± 0.23	46.52 ± 13.15

* = $P < 0.05$ and ** = $P < 0.01$ compared with milk.

More than 50 hormones and growth factors have been detected in milk (Koldovsky 1980; Wang and Zou 1995). They include insulin, prolactin, growth hormone, estradiol, progesterone, insulin-like growth factor I (IGF-I), and epidermal growth factor (EGF). These hormones or growth factors can be absorbed in intact forms by newborn animals such as calves and piglets through colostrum within 24–48 hours after parturition, and hence exert effects on the metabolism and growth of the newborn offspring (Lorraine et al. 1986). Some hormones and growth factors have direct influences on the intestinal development and growth of the suckling offspring (Buts et al. 1988).

Insulin is one of the most studied hormones in milk involved in the early intestinal development and maturity of newborn offspring. Its dynamic change pattern in yak' colostrum was similar to that of other species. The sustained high levels of insulin and prolactin in yak' colostrum might be beneficial to the sucking calves, even after the gut closure, by mechanisms such as the binding of insulin to IGF-I receptor or insulin receptor located in intestinal tissue. The physiological significance of yak' colostrum could be its capacity to provide metabolic signals (hormones and growth factors) and passive immunity to the newborn calves (Zheng and Han 1999).

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Anatomical characteristic of placenta and its relationship with calf birth weight in yak

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Summary

Factors that adversely affect the productive potential of yak include low reproductive rate, low calf birth weight, premature births and high calf mortality under normal grazing and management conditions. In the present study, anatomical characteristic of placenta and its relationship with calf birth weight in yak was studied to investigate causes of low calf birth weight and high calf mortality. The average calf birth weight in the study was 12.44 ± 2.96 kg, which represented $6.41 \pm 1.2\%$ of average dam weight after calving. The average post-partum body weight of yak cows was 187.00 ± 26.98 kg, which was 20% less than the average female weight in breeding season. The average placental weight was 1.58 ± 0.49 kg. Total numbers of cotyledons in pregnant and non-pregnant horns were 45.00 ± 7.11 and 27.25 ± 4.06 , respectively. Total cotyledon area was 1493.94 ± 327.37 cm² and total cotyledon area/birth weight of calf was 123.02 ± 23.44 . These results seem to suggest that malnutrition in the third trimester of pregnancy is the major cause of low calf birth weight and low placental weight.

Keywords: Birth weight, calf, placenta, yak

Introduction

The reproductive rate of yak cows is low under normal grazing and management conditions. Yak females are not mated for the first time until they are 3 years old, and often not until 4 years. Gestation length is around 258 days on average and is shorter than that of cattle. Abortion and other causes of premature termination of pregnancy are between 5 to 10 per cent (Cai and Wiener 1995). The reproductive pattern of yak in Arunachal Pradesh follows the same pattern. Although there has not been any systematic study, field observations suggest that the reproductive rate is generally low under traditional grazing conditions (Pal 1993). The overall low productivity has been attributed to low reproductive rate, low calf birth weight, premature birth and high calf mortality. In Tianzhu White yak' gestation period has been estimated at 255 days, mean birth weight at 11.4 ± 1.9 kg and there is a positive correlation between calf birth weight and supplemental feeding during the cold season (Zhang et al. 1997).

In the present study, anatomical characteristic of placenta and its relationship with calf birth weight in yak was studied to examine the cause of low calf birth weight and high calf mortality.

Materials and methods

In the experimental yak herd, sixteen placentas were collected immediately after expulsion for anatomical observation. The calf birth weight and placental weight were recorded for statistical analysis.

Results and discussion

Placental weight and measurements are presented in Table 1 and the correlation between placental traits and calf birth weight are presented in Table 2. The average calf birth weight was 12.44 ± 2.96 kg representing only $6.41 \pm 1.2\%$ of the average dam weight after calving. The calf birth weight was slightly higher than that reported for Tianzhu White yak of China by Zhang et al. (1997) and for Sangla Velly yak of Himachal Pradesh, India, by Kailla et al. (1997). The average post-partum body weight of the yak cow (187.7 ± 26.98 kg) was 20 per cent less than the average adult female weight in the breeding season (May to October), which was likely due to winter stress and scarcity of green fodder during this period. The average placental weight was 1.58 ± 0.49 kg, which was similar to that previously reported for Tianzhu White yak of China. The total number of cotyledon in yak after birth ranged between 77 and 117 in the present study, a value similar to that for other large ruminants (Stephan 1971).

Table 1. Anatomical characteristic of placenta of yak and its relationship with calf birth weight.

Items	Mean (+/- S.D.) ¹
After birth weight (kg)	1.58 ± 0.49 (1-2.5)
Calf birth weight (kg)	12.44 ± 2.96 (7.5-15.5)
Numbers of cotyledon	
a) Pregnant horn	45.00 ± 7.11 (35.00-58.00)
b) Non pregnant horn	27.25 ± 4.06 (21.00-35.00)
c) Total	98.25 ± 11.13 (77.00-117.00)
Placental length (cm)	
a) Pregnant horn	64.88 ± 8.39 (56.00-80.00)
b) Non pregnant horn	34.63 ± 7.35 (21.00-47.00)
c) Total	85.75 ± 34.37 (77.00-117.00)
Average Cotyledon area (cm ²)	20.55 ± 2.92 (16.38-23.88)
Total cotyledon area (cm ²)	1493.94 ± 327.37 (1015.56-2053.68)
Total cotyledon area/birth weight of calf	123.02 ± 23.44 (96.61-162.39)

1. Figure in parenthesis is the range.

After birth weight was highly positively correlated ($r = 0.914$) with birth weight of calves, indicating the influence of after birth weight and function on foetal growth. The total area of cotyledon had a positive correlation ($r = 0.849$) with the calf birth weight. There was also high positive correlation of average cotyledon area with after birth weight and calf birth weight ($r = 0.949$ and 0.943 , respectively). However, the ratio of total area of cotyledon to calf birth weight was higher in our study compared to that of the Tianzhu White yak of China (Zhang et al. 1994) and many breeds of cattle. The expanded placental area of yak may be an adaptation to the low oxygen environment to facilitate adequate supply of oxygen and nutrients to the foetus. In sheep, Penninga and Longo (1998) reported different types of placentome in high altitude hypoxic singletons and changes in the placentome in spontaneous hypoxic singletons at mean sea level. Penninga and Longo (1998) classified placentome into four different categories ranging from the type associated with the high altitude hypoxic environment to that associated with the physiological hypoxic conditions at mean sea level. This may explain the high ratio of total area of cotyledon to calf birth weight in the present study of yak at high altitude hypoxic condition. To generate more detailed information about the adaptation of yak to high altitude, further studies in this aspect are required.

Table 2. Estimates of correlation between placental traits and calf birth weight.

	1	2	3	4	5	6	7	8	9
1. After birth weight	1.000								
2. Calf birth weight	0.914*	1.000							
3. Total placenta length	0.267	0.046	1.000						
4. Total number of cotyledon	0.443	0.268	0.168	1.000					
5. Cotyledon area pregnant horn	0.845*	0.776	0.113	0.752*	1.000				
6. Cotyledon area empty horn	0.797	0.634	0.381	0.879*	0.905*	1.000			
7. Average area of cotyledon	0.949**	0.943**	0.126	0.457	0.918*	0.768	1.000		
8. Total area of cotyledon	0.849*	0.755	0.179	0.798*	0.994**	0.946**	0.879*	1.000	
9. Total area/birth weight of calf	-0.252	-0.511	-0.142	0.651	0.118	0.308	0.265	0.168	1.000

* = $P < 0.05$; ** = $P < 0.01$

It is concluded that if yak are supplemented with concentrate and roughage during pregnancy, particularly in severe winter, calf birth weight and placental weight can be increased and this will result in reduced incidences of calf mortality.

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Effect of milking methods on early growth and development of Huandhu yak calves in Qinghai, P.R. China

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Summary

Thirty mother–daughter and 30 mother–son pairs were arranged into three groups of not-milking, once milking per day and twice milking per day (10 mother–daughter and 10 mother–son pairs for each group) to study the effect of milking methods on the growth and development of calves from birth to 18 months of age. The results showed that the mean live weights of the calves under these three respective groups were 99.0, 76.6 and 58.0 kg at 6 months, 97.6, 78.9 and 64.6 kg at 12 months, and 146.5, 131.9 and 91.0 kg at 18 months of age. The effects of milking methods on live weights of calves were significant. The results strongly suggest that, for a better development of calves and their subsequent production and reproduction, nursing cows should not be milked or, if milked, only once a day.

Keywords: Calf, cow, growth, milking, yak

Introduction

It is well known that the early growth and development of yak calf will affect its production and reproduction later in life. Commonly, local herdsmen milk cows twice, or even three times per day during the peak milking period in most of the yak raising areas. It is unlikely that the yak calf being nursed by such a cow can obtain enough nutrients to meet its early growth and development. This has implications for the productivity of the overall herd. This study was designed to explore the potential growth and development of yak calves under different rearing methods.

Materials and methods

The study was conducted in Datong Draft Animal Reproduction Farm from 1996–1997. The farm is located in the south of Daban Mountain with altitude of 3000–3900 metres above sea level (masl). The mean annual temperature was 0.5–1°C, the lowest temperature

-28°C, and mean annual rain fall 570–610 mm. There were 5200 km² grassland, with which 1700 yak and 2000 sheep were maintained. Thirty mother–daughter and 30 mother–son pairs were arranged into three groups of: 1) not-milking, 2) once milking per day, and 3) twice milking per day. Each group had 10 mother–daughter and 10 mother–son pairs. All animals were grazed on natural grassland without any supplementary feeding.

All experimental yak calves were ear-tagged and weighed at birth, 6 months, 12 months and 18 months of age. Body measurements, including body height, body length, heart girth and cannon bone circumference were taken at each age of measurement. Milking was stopped for all cows on 10th October and calves were weaned the next February.

Results and discussion

Based on the data shown in Tables 1 and 2, it is clear that the growth and development only occurred during the two warm seasons in the intervening period between birth and 6 months of age and from 12 to 18 months of age. Mean relative weight increased by 685.7 and 50.1%, respectively, for calves of the non-milked cows during the two warm seasons. Corresponding figures for calves whose dams were milked once were 527.9 and 67.6% while those for last group (milked twice) were 344.3 and 41.0%, respectively. Weight gain of yak calves was most rapid between birth and 6 months of age. During the cold season coinciding with growth from 6 to 12 months of age, the relative live weight gains were only -1.41, 3.0 and 11.2% for the three respective experimental groups.

Table 1. Live weight (kg) of calves under different milking regimes.

Group	Sex	No.	Weight			Weight			Weight		
			Birth	6 months	gain	12 months	gain	18 months	gain	gain	
1	G	10	13.3 ± 1.8	107.8 ± 13.9	94.5	105.1 ± 11.4	-2.7	152.2 ± 10.3	47.1		
	E	10	12.2 ± 2.2	90.2 ± 7.7	78.2	90.1 ± 5.2	-0.1	140.8 ± 4.2	50.7		
	Average	20	12.6 ± 2.1	99.0 ± 14.2	86.4	97.6 ± 11.6	-1.4	146.5 ± 9.6	48.9		
2	G	10	12.4 ± 2.2	78.6 ± 7.7	66.2	80.6 ± 5.5	2.0	137.2 ± 7.5	56.6		
	E	10	12.1 ± 1.5	74.5 ± 10.0	62.4	77.2 ± 7.1	2.7	126.5 ± 6.2	49.3		
	Average	20	12.2 ± 1.8	76.6 ± 8.9	64.4	78.9 ± 6.4	2.3	131.9 ± 8.7	53.3		
3	G	10	12.9 ± 1.8	58.8 ± 8.5	45.9	65.8 ± 8.2	7.0	94.4 ± 5.9	28.6		
	E	10	13.2 ± 2.0	57.4 ± 9.8	44.2	63.4 ± 8.6	6.0	87.8 ± 4.3	24.4		
	Average	20	13.0 ± 1.9	58.1 ± 9.0	45.1	64.6 ± 8.3	6.5	91.1 ± 6.0	26.5		

All pair-wise differences in live weight between the three groups of yak calves were significant ($P < 0.01$) at all ages, that is, at 6, 12 and 18 months of age. This indicates that the different milking methods had substantial influence on the early growth and development of yak calves.

Because of the limitations of the natural environment, production situation and feed condition in the area, the early growth of yak mainly rely on the cow's milk. The daily weight gains of 6 months old calves were 489 g, 357.8 g and 250.6 g, respectively, for the three

groups in this study. These figures illustrate the extent to which reduced milk available to the young calf does affect its growth.

Although the calves from the group of cows milked twice per day had a compensatory growth during the next warm season, the rate of growth was still much less than it was for the calves in the other two groups.

Table 2. Body measurements (cm) of calves under different milking regimes.

Group	no.	Body measurement	At birth	Six months	Net gain	12 months	Net gain	18 months	Net gain
1	20	Height	53.6 ± 5.5	92.0 ± 4.8	38.4	93.3 ± 4.2	1.3	9.6 ± 2.8	6.3
		Length	49.9 ± 3.8	96.7 ± 5.7	46.8	98.3 ± 4.9	1.7	104.1 ± 5.1	5.8
		Hear girth	57.7 ± 7.0	123.9 ± 7.7	66.2	125.8 ± 4.7	2.0	137.6 ± 4.3	11.8
		Cannon bone circumference	8.7 ± 0.9	13.4 ± 1.4	4.7	15.0 ± 1.4	1.6	17.8 ± 1.0	2.8
2	20	Height	50.6 ± 5.7	88.0 ± 3.7	37.4	89.4 ± 3.2	1.4	91.5 ± 2.4	2.1
		Length	48.7 ± 5.6	88.5 ± 4.0	39.9	91.6 ± 5.5	3.1	102.3 ± 3.5	10.7
		Hear girth	53.2 ± 4.7	108.8 ± 6.5	55.6	111.4 ± 4.5	2.6	122.2 ± 5.8	10.8
		Cannon bone circumference	8.5 ± 0.5	13.6 ± 1.1	5.1	14.2 ± 1.0	0.6	18.8 ± 1.1	4.7
3	20	Height	53.7 ± 3.4	81.1 ± 3.4	27.4	82.0 ± 3.2	0.9	90.6 ± 1.4	8.6
		Length	48.6 ± 3.7	83.4 ± 4.3	34.9	85.7 ± 1.8	2.3	94.7 ± 1.5	9.0
		Hear girth	54.3 ± 5.5	101.1 ± 6.0	46.9	101.1 ± 4.50	0	116.2 ± 3.9	15.1
		Cannon bone circumference	8.6 ± 0.6	12.0 ± 1.1	3.4	12.6 ± 1.0	0.6	15.1 ± 0.8	2.5

We suggest that cows should not be milked if they have twin calves, are nursing their first calves, or are in their later stages of production (that is, advanced parities). Definitely, for veal production, which requires raising calves on milk and slaughtering by weaning, milking should not be practised at all. We also recommend that cows nursing calves which have been selected as replacement heifers or bulls should not be milked. To meet the milk demand by the local herdsmen, the method of milking once per day may be adopted in the normal management. However, the twice milking per day should strictly be forbidden to improve the quality and production of the herds.

Calves should be weaned at 6 months of age if their dams are not milked or only milked once per day to renew the cows' body condition so that they can be in oestrus and be mated the next breeding year. This is the only way to increase reproductive performance in the yak herds.

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Dentition in yak

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Summary

Age determination is essential in studies on the comparative anatomy, physiology, morphology and taxonomy. In case of ungulate the age is determined on the basis of replacement of the milk teeth by the permanent teeth and by studying the rate of wear of the permanent teeth. In some of the methodology the ratio of the length of the root to the crown is used in age determination. This study presents some observations on the appearance and physical structure of tooth in yak from birth to old age. Basic differences with cattle are: the yak calf is not born with incisors; after a day or two a small speak of white dentine appears on the hard red mass of the incisor gum pad; the first pair of incisors is subsequently followed by eruption of the rest of the incisors; the red hard mass gum pad separates out to make space for the erupting incisors; and by two years of age all the milk teeth come out, the length and width varying from 1.2 to 1.6 cm and 0.6 to 1.1 cm, respectively. On completion of two years the first pair of baby incisor is crowded out by permanent incisor. The process repeats each year until at five years all the four pairs of the baby incisor are replaced by permanent teeth. From five years onwards, the age is estimated by observing the wear and tear of the incisors, which are proportional to the age of the animal.

Keywords: Age, dentition, yak

Introduction

Accurate age determination is an essential requirement to understand some of the major biological phenomenon in animals. Without reliable data on animal age, the rate of growth, sexual maturity, span of reproductive life or the entire life span is rather very difficult to determine. Age determination is also essential in studies on the comparative anatomy, physiology, morphology and taxonomy. Age determination thus enables one to perceive the rate of reproduction and the longevity of the animal. It also helps in the determination of the fluctuations in animal numbers that is going on in a population, thus in turn it can be used to establish the age composition of a population, relative size of the different age groups etc. Age structure is also useful in assessing population status in terms of potential risk of extinction.

Age determinations in the animal species have specific significance. The domestic animal's reproductive life span is important. For economical exploitation, herdsman would like to keep a herd structure, which consists of greater number of animals in the most productive age group so as to optimise profit over time.

Materials and methods

Different methods for the determination of age have been used. One of the oldest methods is to determine the age of the animal depending on the amount of wear and tear of the teeth, specifically in case of the carnivores and rodents. In the case of ungulates, the age is determined on the basis of replacement of the milk teeth by the permanent teeth and by studying the rate of wear of the permanent teeth. In some of the methodology the ratio of the length of the root to the crown is used in age determination. The relative breadth of the tooth canal has also been used in determining age in some species of animals.

In mammals, and also in other species, the external structure of the skull, diameter of the foramen (long preserved specimen), the rate of the fusion of the cranial sutures, the character of the surface and rate of ossification of the epiphyses of the limb bones are used to ascertain the age of the subject. In mammals, the weight of the lens of the eyeball is also occasionally used to determine age.

Examination of the number of ridges on the hooves and horns has been used to determine age in cattle. This method has been found to be somewhat reliable only when claws have not been subjected to extensive wear and tear (Klevazel and Kleinenberg 1969).

Possibly among the Bovidae family, age determination based on horn, hoof or dentition yield different results. This is not surprising since animals are reared under variable agro-climatic conditions where uniform nutrition is not available. This study presents some observations on the appearance and physical structure of tooth in yak from birth to old age.

Before focusing on the processes of wear and tear of the teeth in relation to age, a brief description of the morphology of the tooth is warranted. The tooth of a mammal has two distinct parts: a) the crown, and b) the root. The portion above the gum or jaw is the crown while the embedded portion is the root. The crown is covered from outside to inside by: a) enamel b) dentine, and c) pulp. The root is covered by 'cement' on outside followed by dentine and pulp. The newly erupted tooth is a thin-walled dentine cap whose crown is already covered with enamel.

The dental formula in case of cattle has been established. There are two types of teeth, the deciduous (milk teeth), which later is replaced by a set of permanent teeth. The dental formula is as follows:

Deciduous: 2 (DI 0/4; DC 0/0; DP 3/3)

Permanent: 2 (I 0/4; C 0/0; PM 3/3; M 3/3)

DI = Deciduous Incisor; DC = Deciduous Canine; DP = Deciduous Premolar; I = Incisor; C = Canine; PM = Premolar; M = Molar

Results and discussion

The dental formula holds good for cattle and buffaloes, and is considered applicable in the case of yak as well, but with modifications to accommodate some basic differences at birth and at subsequent ages. Results presented here are based on observations based on yak at various stages of growth and are compared to the pattern of dental development in cattle.

At birth: Yak calf is not born with any baby tooth. The lower jaw at birth is a continuous red hard mass. In some of the newborn calf, very small-pointed edges of dentine appear on the outer corner of both the first pair of incisors. Conspicuous changes take place within seven days of birth. The first pair of incisors appears, the red hard mass starts showing demarcations and there are distinct signs for the appearance of incisor teeth.

After seven days following birth: The beginning of the second week is marked by the complete exposure of the first pair of incisors. The second pair of incisors is still embedded in the red hard mass but the third pair shows up as a small pointed dentine speck on the hard mass. The fourth pair of incisors is still inside the red hard mass.

After fourteen days following birth: The first pair of incisors is broader and bigger. The second incisor has appeared but smaller than the third but the fourth incisor is yet to show up. The red mass in between the incisor is retracted producing gaps between the incisors.

At completion of third week of age: The first, second and third pairs of incisors have grown bigger and comparatively rounder compared to the second week. The fourth pair of incisors is yet not erupted but there is sign of eruption, the bulging of the red mass at the place where the fourth incisor is to come out is prominent.

At completion of fourth week: The fourth pair of incisors has just erupted and starts to grow. The rest of the incisors have also grown in length and breadth. The wide gaps between the incisors have been reduced to a great extent.

Basic differences with cattle up to one month of age:

1. In cattle the calf is born with two or more baby teeth. A yak calf is born without any baby tooth.
2. Subsequent eruption of incisors is spontaneous. Generally every seven days one pair of incisors erupts and by the end of 4th week, the 4th pair of incisors erupts in yak. In cattle the incisors also erupt by 4th week but the length and breadth (size) differ. These are small in case of yak calf. The wide gaps disappear giving space to the incisors.
3. The upper edge of the incisors is sharp and uneven. With advancement in age the uneven edges tend to become even.

Crowding out of baby teeth by permanent teeth: At about two years of age, the first pair of the baby incisors is crowded out by a pair of permanent teeth. At three years of age the second pair of the incisors is replaced by the permanent teeth. The third pair at fourth year and the fourth pair at fifth year of age are crowded out. These phenomena are similar to cattle. The baby teeth are flat, long and wide at the initial stages but as age advances these become smaller and smaller in size until they are completely weeded out by permanent teeth.

The diametrical distance between the two fourth incisors also varies according to the age of the animal. The average distance in yak is 8.46 ± 0.25 cm, with minimum and maximum distances of 7.00 and 10.50 cm, respectively. The distance increases with age. The milk incisors up to two years are large, chiselled out and angular at the upper end and as the time of crowding out comes closer, the upper edges become flat. From a visual examination of the milk teeth on or before two years, an expert can predict approximate age of the subject. The milk incisors' length and width vary from 1.2 to 1.6 cm and 0.6 to 1.1 cm. At five years of age when the mouth is full (all baby teeth replaced by permanent incisors), the maximum length and width of the incisors are 2.0 cm and 1.4 cm, respectively and the corresponding

minimum length and width are 0.8 and 0.8 cm. The length and width proportionately decrease with the age, with a tendency to flatten out almost at a prime age, but this will depend on the type of the grazing available. In old yak above 20 years, only a remnant of the incisors is left.

Conclusion

1. Yak calf is not born with incisors.
2. After a day or two days a small speck of white dentine appears on the hard red mass of the incisor gum pad.
3. The first pair of incisors is subsequently followed by eruption of the rest of the incisors.
4. The red hard mass gum pad separates out to make space for the erupting incisors.
5. By two years of age, all the milk teeth come out, the length and width varying from 1.2 to 1.6 cm and 0.6 to 1.1 cm, respectively.
6. At the age of two years permanent incisors crowd out the first pair of baby incisors. The process repeats each year until at five years all the four pairs of the baby incisors are replaced by permanent teeth. From five years onwards, the age is estimated by observing the wear and tear of the incisors, which are proportional to the age of the animal. A full-grown incisor is 2.0 cm in length and 1.4 cm in width, chiselled at the upper edge but angular inward. The chiselled edge becomes flattened and angular, wearing out as age advances.

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Body weight growth model of Datong yak in Qinghai

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Summary

This study was conducted to develop a suitable model for describing the growth pattern of the yak. The data used consisted of body weight records of 76 growing yak aged between 5 to 37 months. Three mathematical models were applied to describe the growth curves during this development period:

1. $Y_1 = 20.105 + 11.250x - 0.526x^2$

used for describing the growth curve of yak aged 5 to 13 months;

2. $Y_2 = -359.687 + 49.977x - 1.249x^2$

used for animals aged 13 to 25 months; and

3. $Y_3 = -833.339 + 63.772x - 1.019x^2$

used for animals aged 25 to 37 months.

Keywords: Growth, mathematical model, yak

Introduction

Yak (*Bos grunniens*) has a growth pattern which is significantly different from that of cattle (*Bos taurus*). Suitable growth models for cattle breeds have been developed. In China, some studies of growth models have been done for the Chinese yellow cattle breeds such as Anxi cattle, Yianbian cattle and Fujian cattle (Qiu and Ju 1989; Wang 1990; Liang et al. 1995). Although preliminary analyses have been reported in yak growth behaviour (Lu 1981; Ma and Du 1982; Zhang 1989; Cai 1992; Lu et al. 1994), no model is available to describe its growth pattern. The main reason for this has been the general lack of systematic body weight records. This study was conducted to develop suitable models to describe the growth model of Datong yak in Qinghai and to establish the relationship between age (X) and body weight (Y).

Materials and methods

Environment and animal management of the farm

The grazing consisted of mountain meadow located at an altitude of 2900 to 4800 metres above sea level (masl). Annual average temperature at the study location is 2–4°C, ranging from –28°C in January to 24°C in August. The farm has an area of 330 thousand hectare, of which about 200 thousand hectare is grazing land. The biomass output changes seasonally, the highest output being in August and the lowest in April. The average biomass output was 1500 kg/ha (Xie et al. 1997). There were 17 thousand heads of yak raised on the farm. The reproductive yak were organised into different herds with about 150 individuals per group. The calving season spans from March to June but is mostly concentrated in May. Calves are weaned the following March at about 10 months of age and moved into heifer herds. The yak generally are sexually mature at about 3 years of age when they are gradually introduced into the breeding herds. Nursing cows are milked once a day.

Animals

Experimental animals consisted of growing yak aged 5 and 37 months. Animals were weighed bimonthly throughout the year. Experiment animals were the offspring of nucleus breeding herd organised by the Lanzhou Institute of Animal Science of Chinese Academy of Agricultural Sciences since 1990. Most cows had 3 deliveries at the time of the study. A total of 76 yak with relatively complete records and born in 1997 (G1), 1996 (G2) and 1995 (G3) were involved in the study. G1 had 31 animals (15 males and 16 females), G2 had 30 animals (12 males and 18 females), and G3 had 15 animals (8 males and 7 females). Animals were weighed bimonthly from 26 September 1997 to 26 May 1998, a total of 5 weighing. G1 was involved in recording after weaned at 5 months old.

Age assignment

All animals in the study had similar genetic background. As most calves were born in May, the animals in G1 were around 5 months old at the first weighing (26 September 1997), and 15 months at the last weighing (26 July 1998). The age range of the animals in G2 and G3 were around 17 to 27 months, and 29 to 37 months, respectively.

Formulating the growth curve

A preliminary growth curve was derived based on a total of 17 mean weight records of yak aged from 5 to 37 months. From this, three equations of the general form $Y = a + bx + cx^2$ were used to describe the growth pattern of animals in the three growth periods described above.

Results and discussion

Growth curve and mathematical models

The growth curve of the Datong yak is demonstrated in Figure 1. Three mathematical models were formulated to describe the growth curves:

$$Y_1 = 20.105 + 11.250x - 0.526x^2$$

used for describing the growth curve of yak aged from 5 to 13 months,

$$Y_2 = -359.687 + 49.977x - 1.249x^2$$

used for yak from 13 to 25 months, and

$$Y_3 = -833.339 + 63.772x - 1.019x^2$$

used for yak from 25 to 37 months. The respective coefficients of determination were: $R_1^2 = 0.863$; $R_2^2 = 0.728$; and $R_3^2 = 0.840$. All the coefficients were significant, indicating that the models fit well.

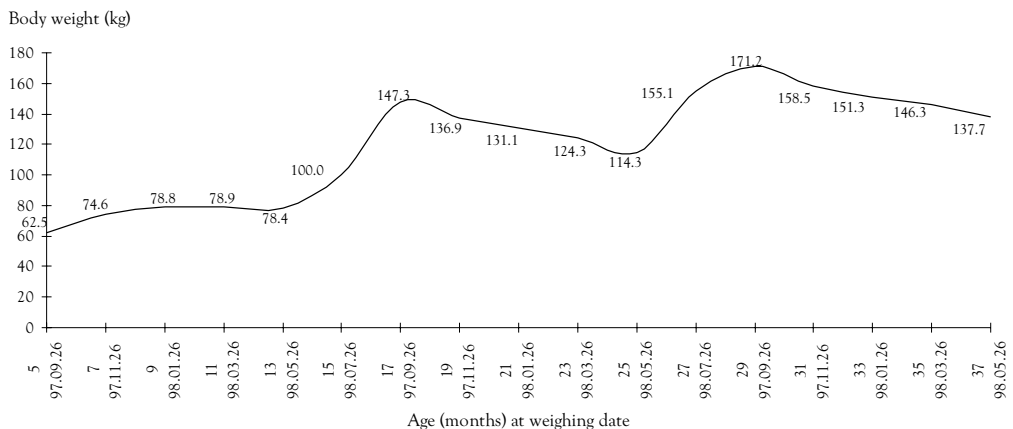


Figure 1. The growth pattern of Qinghai Datong yak.

Characteristics of yak body weight growth model

The yak is a pure grazer and its growth largely depends on the biomass and grass nutrients of the pasture, changing among seasons. Yak experience weight gain during the warm season from June to October and weight loss during the cold season from November to following May. The ratio of body weight gain to loss decreases with increasing age until body maturity (at about 7 years of age for males and 5 years for females) and the ratio tend to be about 1. Hence, the growth pattern of the yak consists of peaks (the heaviest weights) and valleys (the lightest weights) occurring every year. In contrast, cattle under barn feeding or semi-barn feeding usually have a relatively stable growth curve (experiencing less environmental effects) and one

peak value of growth during its lifetime. For this reason, one model suffices to describe the growth curve in cattle and the R^2 value is usually higher (>0.90) than that of yak.

The relationship of weight gain and age

From Figure 1, it can be seen that G1 calves were continuously gaining weight from 5 to 11 months (the end of September to the end of March), and had only a slight 0.5 kg weight loss at 13 months at the end of May. For the older animals (G2 and G3), the weight loss started from the end of September until the end of May. One reason for this is that the G1 calves were kept with cows and were able to get some milk and this made up for the lack of feed supplement during the cold season. Another reason for the difference in the weight change between G1 and the other two groups is that the younger animals (G1) possess greater potential for growth than that the older counterparts (G2 and G3) as is the case in all species. The growth potential differences were investigated in this study by comparing the peak values of weight among ages. The mean birth weight of calves was 12.5 kg ($n = 60$, Wang Minqiang 1993–1994, unpublished data of the Datong Farm). By the age of 11 months, the calves had gained 66.4 kg. From 11 to 17 months, the heifers (G2) gained 68.4 kg. But from 17 to 29 months, the G3 group gained only 33.8 kg. The results showed that the weight gain of the growing yak in the warm seasons before the age of 1.5 years are 2 times that of yak aged between 1.5 to 2.5 years. Compensatory growth may play an important role in the body weight gain of the younger animals.

The relationship between weight gain and seasonal changes

From the end of May to the same time the following year, the G1 animals had grown up to G2 age group and had, therefore, experienced the 2nd growth period. The heaviest weight (147.3 kg) occurred at the end of September and the animals had gained 68.9 kg from 13 to 17 months of age in the warm season, an average daily gain of 0.561 kg. After this period, the animals gradually lost weight as the grass withered until they were 25 months old (from the end of September to the end of next May), losing a total of 33.0 kg during the 8 months. The animals of G3 gained 56.9 kg in the warm season with an average daily gain of 0.463 kg, but they lost an average of 33.5 kg in the cold season. Generally, the yak gain weight only in the very limited 4 months of warm season, but lose weight during the long 8 months of the cold season. Except for the younger animals in G1, the heaviest weight was recorded at the end of September and the lightest weight in the month of May every year.

Optimum yak slaughter age and supplement season

An impressive ratio of weight gain and loss was attained from the study. From birth to 37 months of age (137.7 kg) the animals achieved a net weight gain of 125.2 kg. However, the loss in 3 cold seasons summed up to 67.0 kg, which is more than half of the gain. Two larger

weight loss periods occurred in September to November and March to May for G2 and G3 animals, respectively. The weight loss during March to May represents the most significant check on the growth of all animals, but is especially debilitating to the younger animals, which are usually in poor body condition at this time. These results suggest that this is the period during which supplementary feeding could be most effective. The optimum slaughter time should be around October. From the point of economic efficiency, animals should be slaughtered around 2.5 years of age.

Acknowledgements

The authors are most grateful to all the herdsmen who assisted in weighing the animals. Special thanks are due to Hue Shouhai, Zhao Longquan and Han Kai, the managers of the farm, for managing the experimental animals and ensuring that weighing was done on schedule, even in the coldest seasons.

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Growth patterns of F₁ calves of wild × domestic yak

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Introduction

This study was undertaken in 1999 to investigate the growth pattern in young crossbred calves produced by inseminating Mongolia domestic yak cows with frozen semen of wild yak imported from China. The measurements taken were body weight and linear body measurements at birth, at 7 days and at 14 days of age. Thirteen crossbred semi-wild yak calves were compared against 13 domestic yak calves and 13 Khainag calves (crosses of cattle bulls mated with female yak). The later two groups were taken as controls. These studies were undertaken in Ikhtamir sum, Arkhangai Province.

Results and discussion

Phenotype appearance

The F₁ (wild × domestic) yak calves were brown in colour, with dark brown and black stripes over the top line of the body, and whitish spots around the orbits. Ears were shorter by 1.8–2.3 cm than those of domestic yak calves. The body wool covers were also shorter by 0.8–1.2 cm, with top ends rolled up. The animals were sensitive to the presence of humans and dogs and tended to quickly get away. Natural instincts in newborns, such as sucking and ability to recognise their mothers, were highly developed compared to that in domestic and Khainag calves. They quickly stood up, say, between 15–18 minutes after birth.

Body weight

The average body weight of F₁ calves was 13.4 kg at birth, while that of the domestic yak and Khainag calves was 12.1 and 15.1 kg, respectively. After two weeks the F₁ calves added 2.9 kg (21.6%), which was 2.6–3.5 times higher than that the net weight gain of the two control groups over the same period. Daily body weight gain for the first two weeks of neonatal life

in the F₁ calves was 0.207 g, while corresponding values for the domestic and Khainag calves

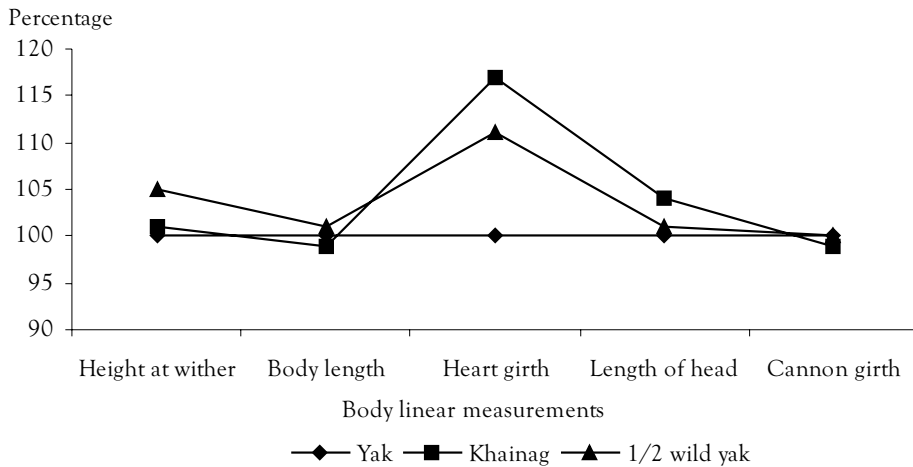


Figure 1. Growth rate of F₁ domestic and Khainag yak calves (kg).

were 0.107 and 0.071 g (Figure 1).

Body conformation

To provide specific details on conformation differences, if any, between the F₁ calves and the controls, basic linear body measurements were obtained for building a conformation profile. The body measurements of domestic yak calves at birth were used as reference (i.e. 100% in Figure 2) and those of the other two groups were calculated in relation to these. In

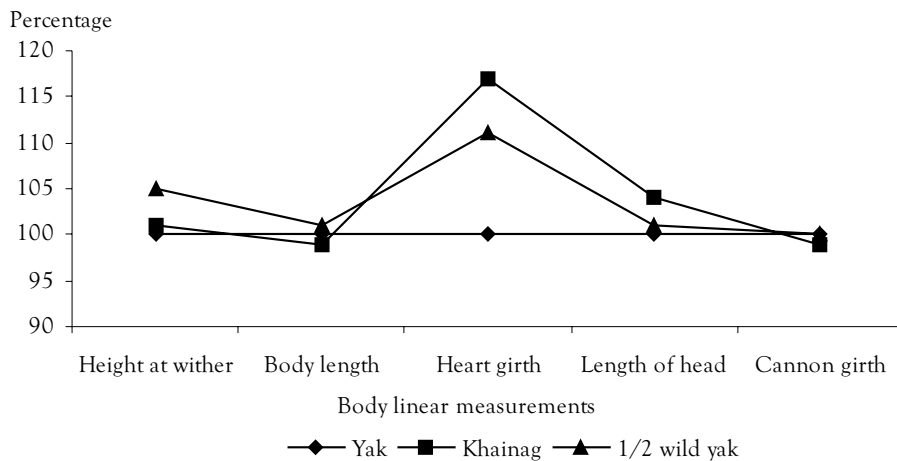


Figure 2. Comparative body conformation profile.

terms of the basic linear body measurements, F_1 calves took an intermediate position between the domestic yak calves and khainag calves. The F_1 calves had higher withers height, had short and narrow heads. The chest was deeper and wider than domestic yak calves.

Purebreeding has been the dominant practice in yak production in Mongolia. Due to rapid decline in heterosis from cattle-yak hybrids when mated with one of the other parental species, the share of khainag yak in the total yak population has been very limited (Zagdsuren 1994). No remarkable improvement in the productivity of yak is also achieved because of infertility of male khainag yak. This is a major constraint to this kind of crossbreeding in the yak. Thus, crossing of yak with the genus *Bos* is not always recommended as a means to increase productivity. To explore opportunities of using wild yak populations to increase growth, a series of studies have been conducted in China (Yang et al. 1997) which showed increases in both growth and milk yield. Specifically, Yang et al. (1997) reported that F_1 calves were heavier at birth and had higher body measurements (body height, heart girth and cannon girth). The findings of the present study are generally in agreement with these previous results.

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Analysis of growth pattern and production function of yak around the Qinghai Lake, P.R. China

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Summary

Body weight data were used to model growth curves by cubic equation and Brody's regression equation. The results show that the cubic equation is suitable for modelling the growth pattern of yak. Tianjun yak had the highest growth efficiency. Although Haiyan yak had the highest body weight, its growth rate was relatively lower than that of Tianjun yak.

Keywords: Growth function, Qinghai Lake, yak

Introduction

Due to lack of scientific information on growth pattern of yak, the composition of yak herds tend to be *ad hoc*. Herders have no idea on how to plan production cycle, e.g. a proper marketing strategy based on growth pattern of animals. As a result, the average age of animals in yak herds has usually been relatively high, which leads to lower production efficiency and severe grazing pressure on pastures.

Many equations have been proposed to model growth in animals, but only the index model, Logistic model, Brody model and Gompertz model have been used, to varying degrees, in predicting the growth patterns of livestock and poultry (Parks 1970; Zhang 1998; Zhang and Yang 1998). To date, these growth models have not been applied on yak. This study was conducted to identify mathematical equations, which can be applied to model the growth pattern in yak and to predict marketing age of yak.

Materials and methods

Herds in three counties, Tianjun, Haiyan and Gonghe, in the areas surrounding the Qinghai Lake, Qinghai Province, were used for this study. All animals were maintained on natural pasture. Body weights were recorded by weighing 50 yak of similar ages in each group. Six and/or 7 age groups were available in the three respective herds studied in Haiyan, Tianjun and Gonghe counties (Table 1).

Table 1. The age points at which yak were weighed (years).

Sites	W ₀	W ₁	W ₂	W ₃	W ₄	W ₅	W ₆	W ₇
Gonghe	0	0.417	1	2	3	4	5	7
Tianjun	0	1	2	3	4	5	7	
Haiyan	0	1	2	3	4	7		

W₀ = primary weight, W₁ to W₇ = weights taken at seven different age points.

Brody and cubic equations were used in this study to describe the growth pattern of yak. The mathematical expressions of these equations are:

Brody: $W = a + b(1 - e^{-ct})$.

Cubic equation: $W = at^3 + bt^2 + ct + d$,

where, W = body weight; t = time; and a, b, c and d are constants.

Results and discussion

Growth rate of yak

Generally, body weight of male yak was significantly heavier than that of female yak (P<0.01). However, there were no differences (P>0.05) in birth weight between sexes, within the same breed (Table 2). Growth efficiency of the three yak populations is illustrated in Figure 1. The figure shows that the Tianjun yak had higher growth efficiency (P<0.01) than Gonghe and Haiyan yak. Although Haiyan yak had the highest birth weight (P<0.01), its growth rate was lower.

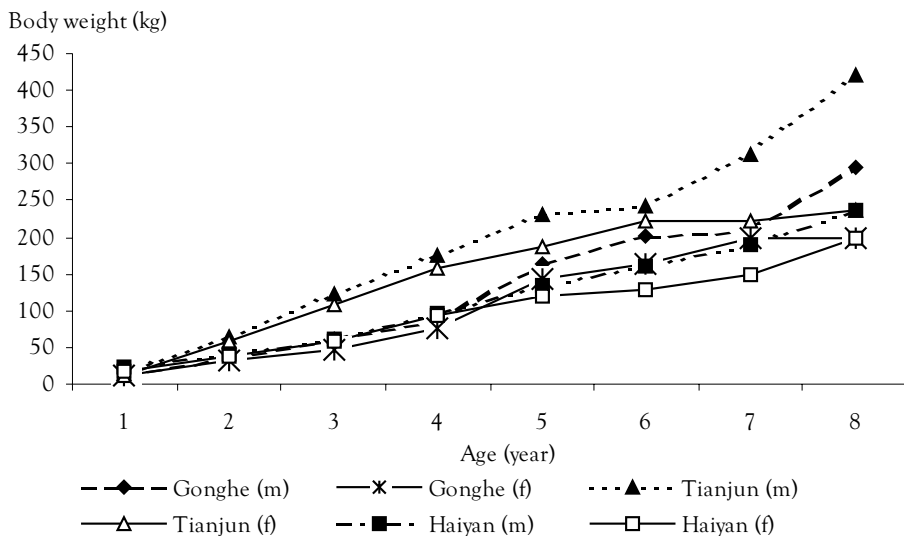


Figure 1. Production function of yak in the areas surrounding the Qinghai Lake.

Table 2. Least square means of yak body weight.

Site	W ₀	W ₁	W ₂	W ₃	W ₄	W ₅	W ₆	W ₇
Gonghe G	10.51	35.97	62.00	84.35	162.4	201.7	206.7	295.6
GongheE	10.25	32.30	46.58	76.19	143.2	162.5	198.0	198.5
Tianjun G	13.59	122.7	174.1	229.4	241.7	313.7	421.0	
Tianjun E	13.14	109.4	158.3	188.3	221.0	221.8	236.7	
Haiyan G	24.25	60.28	97.78	133.2	161.7	237.1		
Haiyan E	18.85	57.99	94.18	120.9	128.7	197.8		

W₀ = primary weight, W₁ to W₇ = weights taken at seven different age points.

Modelling yak growth curve

Zhang (1998) reported that Brody, Bertalanffy and Gompertz were the most suitable growth models for cattle and that the Brody equation gave the best fit. In this study, however, the cubic equation proved to be a more suitable growth model for yak (Table 3). In addition, the advantage of the cubic equation is that its first derivative provides an estimate of efficiency and every point on the cubic equation corresponds to a different efficiency value. Therefore, it can be used to analyse the efficiency of animal production.

Table 3. Parameters of growth model.

Growth model		Male					Female				
		a	b	c	d	R ²	a	b	c	d	R ²
Gonghe	Brody	-8.4	329.5	-0.4		0.9	-55.3	255.4	-1.0		0.9
	Cubic	0.1	-2.2	51.3	10.9	1.0	-1.4	9.4	22.7	14.5	1.0
Tianjun	Brody	59.4	180.8	-0.7		0.9	15.9	232.8	-0.5		1.0
	Cubic	1.8	-20.5	114.2	17.8	1.0	1.4	-19.8	107.1	15.2	1.0
Haiyan	Brody	-55.8	295.0	-0.9		0.7	110.5	310.9	-0.9		0.7
	Cubic	-0.1	-0.6	38.5	23.7	1.0	0.7	-9.1	53.5	17.1	1.0

Analysing production function of yak

Production function, better known as a total physical production (TPP) in economics, can be used to obtain marginal physical production (MPP) and average physical production (APP). MPP is the amount of product output per unit of resource input. In mathematics, it can be defined as the first derivative of TPP, that is: $MPP = dW/dt$. TPP models in this study are all cubic equations, so MPP expression is: $MPP = ex^2 + fx + g$. The three parameters, e, f and g are summarised in Table 4. APP is the average gain of animal within a certain period. Its mathematical expression is $APP = TPP/year$. In this study, APP decreased with age.

A desirable animal production system is that which is characterised by the highest productivity and the highest efficiency. To achieve this, production should be maintained at a point where the productivity (APP) is at its highest level while the resource output rate

Table 4. Parameters of MPP.

Sex	Gonghe			Haiyan			Tianjun		
	e	f	g	e	f	g	e	f	g
Male	0.26	-4.36	51.28	-0.22	-1.28	38.53	5.34	-41.01	114.22
Female	-4.05	18.89	22.66	2.20	-18.18	53.48	4.05	-39.57	107.07

remains at a high level. Mathematically, the best status of animal production could be expressed as $MPP = APP$. To determine the best marketing time, we should also consider the relationship of resource input with the productive output. So, the age that best fits the relation $MPP = APP$ is the appropriate marketing age. The results of this study indicate that the possible marketing age for both male and female yak in Gonghe is 2 years, while for male and female in Tianjun the right ages are 6 years and 1 year, and in Haiyan the corresponding ages are 4 and 6 years. However, due to the limited samples, this conclusion needs further confirmation.

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Session VI: Disease and health service

Reindeer (*Rangifer tarandus*) and yak (*Bos (Poephagus) grunniens*): Disparate animal species—similar environment, management and parasite problems?

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Summary

Reindeer (*Rangifer tarandus*) inhabit most of the circumpolar land areas not covered by permanent ice in the Palaearctic (Eurasian) and Nearctic (American) regions of the northern hemisphere. In the northern areas of Sweden, Norway and Finland (Fennoscandia), home to the Saami people, reindeer are a crucial resource and large populations are maintained under semi-domesticated situations. There has been departure somewhat from the transhumance type of management in recent years, but still these animals are herded extensively on alpine pastures and browse, in accordance with the seasonal availability of feed. In many ways, this approximates the management systems for yak (*Bos grunniens*) in the cold, high altitude areas of central Asia. Therefore, it is not surprising that similar species of parasites (both internal and external), with similar features and rank order of importance are found in these two quite different animal species. The warble fly (*Hypoderma* spp) is generally regarded as the most important parasite of both reindeer and yak. The immature stages cause considerable stress to the animal through the migratory activities, and economic loss due to damage of the hide following the emergence of the pre-pupal stages. For reindeer, the incidence of infection can exceed 95% of the herds. Hypodermosis, particularly of the white yak populations in the Tianzhu region of China, is a particularly serious disease with prevalence of infection approximating 100% and responsible for great losses in productivity. Gastro-intestinal nematode parasites are also important in both reindeer and yak. In reindeer, the abomasal parasite *Ostertagia gruehneri* is the most common and economically important. Yak have been shown to harbour a range of nematode species, similar to those found in cattle in the cool temperate regions of the world, with *Ostertagia* spp considered to be one of the most important internal parasites. Control of these parasites is essential if economic losses are to be reduced, or avoided, for both reindeer and yak production. This poses many logistical and practical problems which are not associated with control of parasites in more sedentary systems of livestock management—such as for cattle, sheep and goats.

Keywords: External parasites, internal parasites, reindeer, yak

Introduction

The reindeer genus *Rangifer* comprises only one species, *R. tarandus* living in the northern hemisphere, both in the Palaearctic (Eurasian) and Nearctic (American) areas (Banfield 1961). It inhabits most of the circumpolar land areas not covered by permanent ice. The southern most reindeer (apart from those introduced to the southern hemisphere) graze in China (50) and the northern most on Svalbard, Greenland and arctic islands of Canada (Oksanen 1999). There is some controversy as to the number of subspecies of reindeer, with a range between 7 and 12. It seems that one of the most important reasons for the evolution of subspecies has been the separation of the Asian and American continents and the concomitant occurrence of a series of glacial periods (Oksanen 1999). The Nearctic wild reindeer is called the caribou.

The current estimate of the total reindeer population of the world is nearly 8 million animals, with half of them semi-domesticated (Staal and Nieminen 1993). About 20% of the semi-domesticated reindeer are in Fennoscandia (Finland, Sweden and Norway) and 75% in Russia. The remaining 5% are found in North America and Greenland, and on arctic and sub-antarctic islands (Oksanen 1999).

The main reindeer product is meat, but also hides are an important source of income. In Russia, reindeer are still an important draft animal. They are also milked and used for riding at some locations (Nieminen 1995). Velvet antler constitute the major reindeer product in Alaska for sale to Asian markets (Nieminen and Muhonen 1996).

Within the Fennoscandian region, reindeer husbandry is almost entirely associated with the indigenous Saami people. Management is under a co-operative system, whereby animals are owned by individual herders, but they graze communally. The number of animals has increased rapidly in recent years, largely due to changed management techniques which include winter supplementary feeding, antiparasitic treatment and motorised herding. This has placed considerable demands on the sustainability of this industry, not least of which is the pressure on the environment induced by overgrazing (Oksanen 1999).

The adaptations of the yak (*Bos (Poephagus) grunniens*) to extremely cold climatic conditions are rather similar to those of the reindeer. In addition, there are other physiological adaptations (large heart, lungs and high erythrocyte count), which enable this species to tolerate low oxygen content of high altitude regions (Sasaki 1994). Their habitat is limited to the mountains and plateaus of the Asian highlands, inter-connected mountainous areas of the Himalaya, Pamir, Kun Lun, Tien Shan and Altai mountains (RangaRao et al. 1994). The world population is in the order of 15 million animals, with approximately 90% found within the P.R. of China (Rongchang et al. 1994). There are several native strains or types of yak and this animal can interbreed with cattle, with the hybrids referred to as *dzomo* (female) and *dzoo* (male). This has now become a common practice for the purposes of increasing meat and particularly milk production, but it results in sterility of the male hybrids (Rongchang et al. 1994). Yak are known universally as being an important pack animal in these cold, high mountain regions, but they also produce a range of valuable products, such as meat, milk, hide, hair and dung (used as fuel).

Because both reindeer and yak are the sole animal species of economic importance that survive in their respective regions, they are irreplaceable resources to the local communities. Therefore, factors that adversely affect the productivity of these animals, which potentially can be minimised, are of great importance. Of these, macroparasites (internal and external) are likely to be the most important disease organisms, which limit animal productivity at the extreme latitudes and altitudes of the world.

Parasites—Impact on production

Establishing with any degree of certainty, the financial penalty of parasite infection in a given livestock system is extremely difficult—some would say impossible. A much more relevant approach is to attempt to assess the avoidable losses from parasitic infections, simply because it is totally unrealistic to expect suppression (or eradication) of parasites from any grazing livestock situation (Perry and Randolph 1999). This would particularly apply to extensive, communal grazing activity that typifies the way in which reindeer, or yak, are managed.

It is a common belief amongst reindeer owners that the obvious parasites (larval stages of the oestrid flies—warbles, throat bots) are part of the ‘normal’ appearance of their animals and these, together with the cycles in weather and vegetation, are an inseparable part of reindeer management ecosystem (Oksanen 1999). Nevertheless, attempts to estimate the costs of parasites to reindeer productivity have been made and these range from 20–30% (Nordkvist 1967; Saval’ev 1968). Irrespective of this, reindeer owners are now obviously of the opinion that parasites are a cause of preventable losses in production. This is clearly illustrated by the fact that approximately 75% of all reindeer in Fennoscandia are treated at least once per year with anthelmintic (Oksanen 1999).

It would seem that the effects of parasites, particularly hypodermosis, are even more severe in yak. Studies involving many thousands of yak, where comparisons were made between either treated and untreated animals grazing communally, showed that milk and meat production was increased by 20–30%, and hide damage and mortality were greatly reduced, in the treated animals (Yanhong 1994). Hypodermosis was also attributed to be a significant factor in the cause of high mortality of yak in Bhutan (Choudhuri 1970). The Tianzhu White yak—a rare, mild tempered, native strain of yak found largely in the Gansu Province of China, is particularly susceptible to warble attack, with almost all animals infected at any one time (Yanhong 1994).

Whilst these very limited studies which attempt to estimate productivity/costs of parasites to reindeer and yak industries, are directed entirely towards the obvious parasites (warbles and throat bots), absolutely no information of the penalties of the more cryptic gastro-intestinal and pulmonary nematodes of reindeer and yak exists. However, based on analogy with economic assessments of the cost of internal parasitism in other grazing ruminants (cattle and sheep), these costs are likely to be substantial. This is based on the fact that immunity in grazing livestock to nematode parasites is slow to develop, is dependent on a good nutritional state and pick-up of infective stages from pasture is more-or-less a continuous process. As a consequence, parasites are ubiquitous throughout all the extensively grazed regions of the world and virtually all animals are infected almost all of the time (Waller 1997a).

Parasites of importance

Theory predicts that the most pathogenic parasites are generally rare and thus have little impact on host populations, compared with less pathogenic parasites that may be abundant and therefore suppress host populations to a greater extent (Anderson and May 1978; May and Anderson 1978).

External parasites

The most notable insect parasites of reindeer and yak, excluding harassment by blood sucking insects, are lice and the oestrid flies. Of the latter, the warble fly *Hypoderma/Oedemagena tarandi* (for reindeer) and *Hypoderma lineatum* (for yak) are generally considered the most important, but possibly this is due to the fact that most studies (see above) have been directed towards this pest. *H. lineatum* is the common warble fly of cattle. The throat bot, *Cephenomyia trompe*, may also be important in reindeer, but very little is known about this parasite.

The life cycle of *Hypoderma* is very similar for all species of this genus. Female flies lay eggs on the hairs of the host, especially on the feet, during the summer months. The larvae hatch, crawl down the hair follicle and penetrate the skin, to commence an extensive somatic migratory phase in the connective tissue of the animal. They finally reach their predilection sites, which is the subcutaneous tissue of the back of the animal, where they mature to the 3rd instar larvae. During winter they perforate the skin of the animal to breathe. In spring, the mature larvae emerge, drop to the ground where they bury themselves, pupate and the imagoes emerge about one month later, depending on the prevailing weather conditions (12 \cong 50 days; 27°C \cong 10 days; Nilssen 1997). *Hypoderma* has a specific attraction for light coloured animals; thus this fly particularly troubles white reindeer and yak.

Internal parasites

For reindeer, the brainworm, *Elaphostrongylus rangiferi*, is considered to be the most important, but this could be simply due to the fact that, apart from warble fly, most is known about this parasite (Oksanen 1999). This parasite has been responsible for severe outbreaks of meningoencephalitis after warm summer weather (Handeland and Slettbakk 1994). Very little is known about the lungworm, *Dictyocaulus eckertii*, of reindeer, but it can be present in large numbers in emaciated reindeer calves during late winter (A. Oksanen, personal communication). With regards to the gastro-intestinal nematodes, the abomasal species (particularly *Ostertagia gruehneri*) has been reasonably well studied but mainly in wild reindeer populations on Svalbard (Halvorsen and Bye 1999). The intestinal nematode fauna, such as *Trichostrongylus* spp, *Moniezia* spp, *Nematodirus* and *Nematodirella* spp may also be important. Quantitative data suitable for epidemiological investigations and the development of strategic control methods are lacking almost entirely for most of the parasites of reindeer (O. Halvorsen, personal communication).

A number of studies on the gastro-intestinal nematode fauna of yak have been performed (Liu 1994; RangaRao et al. 1994). As expected, a comprehensive array of species

have been reported, representing the range of important nematode, trematode and cestode species commonly found in bovine and ovine hosts, some being apparently yak-specific. With regards to nematode parasites, it appears that *Trichostrongylus* spp, *Ostertagia* spp, *Cooperia* spp are the most dominant species (Ranga Rao et al. 1994). This observation is in accord to the most abundant nematode parasite species of ruminant livestock found in the temperate regions of the world (Anderson and Waller 1983). Thus, it is reasonable to assume that the epidemiology and principles of control of these parasites in yak would be broadly similar to gastro-intestinal parasites of cattle.

Methods of control

These have been directed primarily at the control of insect pests, particularly *Hypoderma* spp.

Non chemical

Prior to the advent of the effective parasiticides, various management procedures were carried out with varying degrees of adoption for reindeer management systems in the Palaearctic region (Oksanen 1999). Warbles were often removed mechanically from infected reindeer by compressing them between the thumb and the forefinger in spring. However, this procedure was extremely laborious and an alternative, effective mechanical method of individual animal treatment was to suffocate the larval stages by applying thick emulsions, e.g. creosote or tar, to the backs of animals.

Because of their specific attraction to light coloured reindeer, warble fly females were lured to alight on white hides, where they were easily killed. Early knowledge of the seasonal dynamics of *H. tarandi*, led to the development of some ingenious management procedures. For example, resting herds of reindeer in wet, swampy regions in early summertime was carried out with the specific purpose of causing a lot of the emerging larvae to drown. Another practice was to drive herds considerable distances (>50 km) after calving in early summer and not returning to the calving ground until late autumn, to deprive the adult flies with suitable hosts. Dark sheds for housing and the use of smoke screens as repellents during the warm summer months are also traditional methods used to combat this important pest problem in reindeer.

I am not aware of any published information with regards to the control of warbles in yak by non-chemical methods. However, it is possible that one, or a number, of these approaches have been used.

Chemical

With the advent of the modern insecticides (DDT, hexachlorethane, chlorophos and pyrethrin etc.), mass spraying of animals was tested in Russia. One trial showed that the use of 12.5 kg for each of pure DDT and hexachlorethane on a herd of 1000 reindeer during one summer season increased their performance by 5–6 kg/animal and improved the quality of the hides (Savel v 1968). Clearly these are impressive performance data, but one

wonders at what cost to the environment? Fortunately, the questionable economics and the impracticality of such mass treatment (if not the environmental impact) have precluded widespread adoption of these mass insecticide treatment procedures.

Chemical treatment against the larval stages of warbles started to become popular following the advent of the systemically applied organophosphate drugs. Drugs such as famphos, trichlorfon and fenthion have been reported as being effective against the larval stages of both warbles and throat bots of reindeer (Nieminen et al. 1980; Nordkvist 1980) and fenthion has been used against warbles in yak with good success (Yanhong 1994).

However the treatment of the larval stages of these flies took a quantum leap forward with the marketing of the macrocyclic lactone (ML) drugs, most notably ivermectin. These drugs have a very broad range of activity and extraordinary potency against both internal and external parasites—as a consequence they are often termed endectocides. Not only do these drugs have an exceedingly potent activity against nematode parasites at dose levels many magnitudes less than for the other broad-spectrum anthelmintics, but they have quite extraordinary potency against *Hypoderma* spp. For example, the dose rate of ivermectin for most livestock species is 200 µg/kg liveweight, with the dose-limiting species being the gastro-intestinal nematodes (cf. range of \cong 5–50 mg/kg for the other modern broad-spectrum anthelmintics), represents major overkill for warble larvae. A high efficacy was reported at a dose of 0.2 µg/kg of the injectable formulation against *H. lineatum* in cattle—one thousandth of the recommended dose rate for nematode parasites (Drummond 1984).

A series of studies have been conducted on the control of internal and external parasites of reindeer using the ML anthelmintics, principally by Oksanen and co-workers (Oksanen et al. 1992; Oksanen et al. 1993; Oksanen 1996; Oksanen et al. 1998) who have suggested that the most efficacious product is seemingly the subcutaneous injectable formulation of ivermectin. These workers have also evaluated other ML formulations. For example, moxidectin was shown not to have comparable efficacy as ivermectin (Oksanen and Nieminen 1998). Doramectin had 100% efficacy against warbles and throat bots, but this drug was not evaluated against internal parasites (Oksanen and Nieminen 1996). However, it could be expected to have equi-potency with ivermectin against these.

Although no off-label recommendations can be made for any drugs, it is almost certain that the ML anthelmintics would have similar, extremely high levels of efficacy against internal and external parasites of yak. The recommended dose rate to domestic ruminants is the same (i.e. 200 µg/kg for all the commercial MLs for subcutaneous injection and oral administration, and 500 µg/kg as a pour-on application). Although the topical (percutaneous) application has a lot of obvious attractions, this formulation was found to be not as effective as the subcutaneous administration in reindeer (Oksanen et al. 1993; Oksanen et al. 1995). This was attributed to the dense hair covering, thick skin and large subcutaneous fat deposits of the reindeer, which would limit drug bioavailability. The same factors are likely to militate against high efficacy of pour-on formulations of MLs in yak. It is also important to recognise that there are considerable differences within ruminants in the metabolism and pharmacokinetics of the MLs (McKellar and Benchaoui 1996), thus

extrapolations of expected efficacy against similar parasites between animal species must be made with caution.

Parasite treatment strategies

Strategic treatment—Getting the best out of the drug

To maximise the effect of any anti-parasiticide treatment, it is important to link this with the seasonal bottlenecks in the parasite populations, when either the greatest proportion of the population will be exposed to the drug treatment and/or the potential for immediate re-infection is low. Also, every effort should be made to treat the whole host population, which serve as the main reservoir for the parasite population(s). This maximises the benefit of the drug treatment. This is sound in theory, but often difficult in practice, particularly in communal-type grazing systems, which typify reindeer and yak production.

However, it is now recognised that a particularly important time to treat reindeer, from a parasite epidemiology standpoint, is at the time when the animals are gathered in early winter. The parasites are particularly vulnerable, as they have evolved to over-winter almost entirely inside the animals. The warble and throat bot populations consist almost entirely of larval stages within the host and nematode parasites accumulate inside the animals, often in the hypobiotic (arrested) stage of development. Therefore, it is obvious that treatment at this time with a broad-spectrum anthelmintic (a ML) is an extremely sound strategy. This has been now widely accepted by the owners of reindeer in Fennoscandia and thus within a co-operative, almost universal agreement to treat with a ML anthelmintic at winter gathering, is commonplace (Oksanen 1999).

It would seem that the general epidemiological pattern of internal and external parasites of yak would be similar to those of the reindeer. That is, accumulation as larval stages within the animals as the main means of over-winter survival. Therefore treatment of animals at the beginning of winter not only causes a major disruption in the magnitude of the continuing parasite populations in the following year, but also removes potentially damaging parasite populations within the animal. These over-wintering populations compete for the precious nutritional resources of the animal when climatic conditions are extreme.

A word of warning—On resistance

It must be remembered that every time a drug is used, a strong selection pressure is placed on the target parasite population. Any survivors, and these can be exceedingly few with the modern drugs now available, have a great survival advantage. Resistance has been shown to be genetically determined and thus survivors will pass on resistance genes to successive generations. It could be argued that, because of the extreme sensitivity of *Hypoderma* spp to the ML drugs, resistant genes would be non-existent in this important parasite of reindeer and yak. I am not so certain. High levels of ML resistance have been shown to develop in other fly species (Scott et al. 1991).

One potent selector for the development of anthelmintic resistance is high frequency of treatment (Waller 1997b). Thus it could also be argued that treatment of reindeer and yak very infrequently (1–2 times each year) would not impose a strong selection pressure for the development of resistance. Unfortunately this also does not appear to be the case. Occasional strategic treatments have been shown to be potent selectors of resistance in situations where almost the entire parasite populations are within the animal (Besier 1997).

Although ML resistance by the target pest species has not been reported in reindeer or yak, it occurs for other pest parasite species—both flies (Scott et al. 1991) and to a range of both sheep and cattle nematode parasites (Rolfe 1997; Sangster 1999). Of particular concern with regards to all the cases of macrocyclic lactone resistance is that resistance seems to be a single major gene effect. This means that once resistance occurs, it increases rapidly and to a very high level (Le Jambre 1996), where dose levels many magnitudes higher than the recommended dose rate of the drug have no effect on resistant individuals.

I do not wish to conclude this presentation by sounding alarmist. However it must always be remembered that the development of resistance to a particular drug (group) is an inevitable evolutionary consequence in any given target pest species. Rather sadly, this has been shown time and time again (Waller 1994). It is important that reindeer and yak owners are made aware of this potential and for them to use other means of parasite control, both chemical and non-chemical, that are practical, affordable and effective to safeguard against the occurrence of this phenomenon.

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Drug susceptibility test of *Escherichia coli* isolates from healthy yak of Qinghai

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Summary

There is very limited information on the susceptibility of *Escherichia (E) coli* to antibiotics in healthy yak. Disk diffusion susceptibility test, an international standard test, was applied in the drug susceptibility test of 68 strains of *E. coli* isolates from healthy yak in Qinghai to 12 kinds of antibiotics. The results showed that, among the 12 antibiotics, the inhibitory effects of Norfloxacin and Amikacin were the greatest and all the *E. coli* strains were susceptible. The effects of Ciprofloxacin, Chloramphenicol, Ampicillin, Gentamicin, Trimethoprim/Sulfamethoxazole, Kanamycin, Tetracycline and Streptomycin were medium and 52.9–98.5% strains were susceptible to these antibiotics. None of the strains was susceptible to Penicillin and Rifampin. This study suggests that acquired drug resistance is not an actual problem in *E. coli* strains in herds of healthy yak in Qinghai, where antibiotics are rarely used.

Keywords: Drug susceptibility test, *E. coli*, yak

Introduction

More than 90% of the world's yak population is found in China; Qinghai-Tibetan Plateau is the main region of yak rearing (Editing Committee 1989). Yak production is still principally low-input and extensive. Antibiotics are rarely administrated. There is limited information on the susceptibility to antibiotics of *E. coli* in healthy yak. This paper reports results of susceptibility test of 68 strains of *E. coli* isolates in healthy yak from Qinghai to 12 kinds of antibiotics.

Materials and methods

Strains and detection of virulence factors

Sixty-eight strains of *E. coli* were isolated from slaughtered healthy yak in Xining City of Qinghai Province in 1998. *E. coli* of ATCC 25922 (Institute of Microbiology of Academia Sinica) was used as control to quantify the susceptibility. Haemolytic test (Gottschalk et al.

1995) and skim milk plate test (Quinn et al. 1994) were applied to identify virulence factors of haemolysins and extracellular proteases of the *E. coli* strains. *E. coli* SP12 and XZ19 from chickens were used as positive controls.

Antimicrobial disks

Twelve kinds of antimicrobial disks containing Norfloxacin (NOR), Amikacin (AKN), Ciprofloxacin (CIP), Chloramphenicol (CMP), Ampicillin (AMP), Gentamicin (GEN), Trimethoprim/Sulfamethoxazole (SXT), Kanamycin (KAN), Tetracycline (TET), Streptomycin (STR), Penicillin (P-G) and Rifampin (RIF), were purchased from the Shanghai Yihua Medicine Technology Limited Corporation.

Experimental methods

MaConkey culture medium (No. 981217, Jiangsu Health and Epidemic Prevention Station) was used to culture the bacteria. M.H. culture medium (No. 000224, Shanghai Reagents Research Center of Diarrhea Diseases Control of China) was applied according to the K-B method (Carter 1986; Cao 1992). After inoculation for 18 hours, the size of the zones of inhibition was measured to identify the isolates' susceptibility to antibiotics. The zones of inhibition were recorded as susceptible (S), intermediate (I) and resistant (R) in relation to the standards of National Committee for Clinical Laboratory Standards (NCCLS) in USA. The inhibition standard of P-G was from that of Cao (1992).

Results

Detection of virulence factors

Haemolytic test and skim milk plate test both had negative results in 68 strains of *E. coli*, while the control strains SP12 and XZ19 were positive.

Susceptibility test of strains for quality control

The quality control of the susceptibility test of ATCC 25922 to the 12 kinds of antimicrobial disks conformed to the inhibition zones of NCCLS for all items and P-G's susceptibility test was also identical to that of Cao (1992).

Susceptibility test of isolates

The inhibition zones of 68 strains of *E. coli* demonstrated that only one strain was resistant to the antibiotics CMP, AMP, GEN and KAN, two were resistant to SXT, five to STR and eight to TET. No strains were resistant to NOR, AKN and CIP (Annex I).

Among the 68 strains studied, 23 (33.8%) were susceptible to 10 antibiotics, 20 (29.4%) were susceptible to 9 antibiotics, 17 (25.0%) were susceptible to 8 antibiotics, and 7 (10.3%) were susceptible to 7 antibiotics. No strains were sensitive to five or six antibiotics. Only one strain (1.5%) was susceptible to four antibiotics. None was susceptible to one to three antibiotics (Figure 1).

Among the 12 antibiotics, resistance was highest to P-G (77.9% of the *E. coli* strains) and RIF (97.1%). No strains were resistant to NOR, AKN and CIP (Table 1).

Table 1. Resistance percent (R%) and the intermediate percent (I%) of 68 strains of *E. coli* to 12 kinds of antibiotics.

	Antibiotics											
	NOR	AKN	CIP	CMP	AMP	GEN	SXT	KAN	TET	STR	P-G	RIF
R%	0	0	0	1.5	1.5	1.5	2.9	1.5	11.8	7.4	77.9	97.1
I%	0	0	2.9	0	0	1.5	0	26.5	19.1	39.7	22.1	2.9

All the strains were susceptible to NOR and AKN. 52.9–98.5% of the strains had medium susceptibility to CIP, CMP, AMP, GEN, SXT, KAN, TET and STR. The susceptibility of P-G and RIF was the lowest: No strains were susceptible (Table 2).

Table 2. The susceptibility percent (S%) of 68 strains of *E. Coli* to 12 kinds of antibiotics.

	Antibiotics											
	NOR	AKN	CIP	CMP	AMP	GEN	SXT	KAN	TET	STR	P-G	RIF
S%	100	100	97.1	98.5	98.5	97.0	97.1	72.0	69.1	52.9	0	0

Discussion

Yak inhabits the high mountain pasture on the Qinghai-Tibetan Plateau, where, to date, there is no use of antibiotics. In this study, the natural susceptibility to antibiotics of *E. coli* strains from healthy yak was evaluated.

The standards for drug susceptibility test issued by NCCLS and approved by World Health Organization (WHO) were adopted in the test, and the control was *E. coli* ATCC 25922. The drug susceptibility of 68 strains of *E. coli* isolates from Qinghai was tested. Therefore, the results of the experiment should be reliable.

E. coli develops drug resistance easily, either natural or acquired resistance. Our test demonstrated that among the 68 *E. coli* strains studied none was resistant to NOR, AKN and CIP, and only 1.5–11.8% of strains had the medium resistance to CMP and six other antibiotics. Almost 100% strains were resistant to P-G and RIF. The invalidity of P-G to Gram-negative bacillus is well known and RIF is mainly applied to tuberculosis. These results suggested that acquired drug resistance was not a problem in *E. coli* strains in Qinghai yak.

Drug diffusion susceptibility test was only an initial susceptibility test. The determination of minimum inhibitory concentration (MIC), the analyses of plasmids spectrum and the detection of resistant plasmids are subjects of future studies.

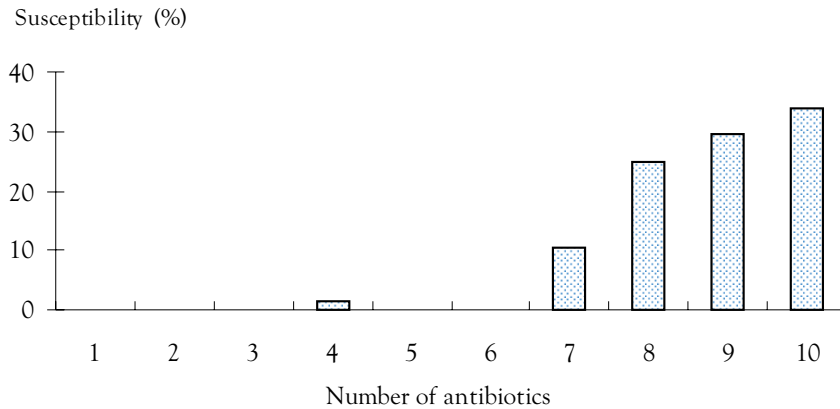


Figure 1. The susceptibility spectrum of 68 strains of *E. coli* to 10 kinds of antibiotics.

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Annex I. Results of inhibitory diameter for 68 strains of *E. Coli* isolates (mm).

No.	Antibiotics											
	NOR	AKN	CIP	CMP	AMP	GEN	SXT	KAN	TET	STR	P-G	RIF
1	21(S)	18(S)	27(S)	29(S)	24(S)	18(S)	33(S)	19(S)	24(S)	15(S)	8(R)	16(R)
2	20(S)	17(S)	20(I)	20(S)	20(S)	17(S)	28(S)	18(S)	21(S)	15(S)	9(R)	10(R)
3	23(S)	19(S)	25(S)	34(S)	25(S)	20(S)	32(S)	20(S)	22(S)	15(S)	19(I)	11(R)
4	22(S)	19(S)	22(S)	29(S)	22(S)	18(S)	28(S)	19(S)	20(S)	16(S)	/(R)	11(R)
5	28(S)	21(S)	32(S)	29(S)	23(S)	19(S)	29(S)	19(S)	25(S)	17(S)	11(R)	10(R)
6	23(S)	20(S)	26(S)	29(S)	24(S)	18(S)	27(S)	19(S)	25(S)	16(S)	14(I)	14(R)
7	22(S)	18(S)	27(S)	25(S)	26(S)	17(S)	27(S)	18(S)	/(R)	9(R)	13(I)	14(R)
8	25(S)	18(S)	28(S)	30(S)	21(S)	21(S)	28(S)	20(S)	27(S)	13(I)	8(R)	11(R)
9	22(S)	21(S)	30(S)	29(S)	24(S)	18(S)	29(S)	19(S)	25(S)	15(S)	8(R)	12(R)
10	27(S)	20(S)	28(S)	25(S)	22(S)	21(S)	28(S)	19(S)	20(S)	16(S)	8(R)	12(R)
11	29(S)	20(S)	30(S)	25(S)	22(S)	21(S)	25(S)	18(S)	20(S)	16(S)	13(I)	10(R)
12	22(S)	19(S)	27(S)	21(S)	22(S)	18(S)	30(S)	19(S)	22(S)	15(S)	/(R)	10(R)
13	21(S)	18(S)	27(S)	31(S)	26(S)	17(S)	30(S)	22(S)	24(S)	13(I)	11(R)	13(R)
14	31(S)	23(S)	32(S)	28(S)	22(S)	23(S)	28(S)	22(S)	20(S)	18(S)	/(R)	13(R)
15	21(S)	20(S)	27(S)	29(S)	38(S)	13(I)	25(S)	20(S)	8(R)	18(S)	17(I)	11(R)
16	26(S)	19(S)	28(S)	27(S)	21(S)	20(S)	30(S)	17(I)	/(R)	14(I)	/(R)	10(R)
17	28(S)	21(S)	36(S)	20(S)	22(S)	21(S)	22(S)	18(S)	15(I)	15(S)	10(R)	11(R)
18	26(S)	19(S)	35(S)	26(S)	19(S)	20(S)	29(S)	16(I)	12(R)	13(I)	/(R)	12(R)
19	27(S)	22(S)	29(S)	26(S)	20(S)	21(S)	28(S)	18(S)	21(S)	15(S)	14(I)	10(R)
20	26(S)	18(S)	28(S)	20(S)	20(S)	19(S)	26(S)	17(I)	/(R)	/(R)	/(R)	9(R)
21	20(S)	18(S)	36(S)	30(S)	20(S)	15(S)	32(S)	20(S)	16(I)	18(S)	13(I)	12(R)
22	29(S)	20(S)	31(S)	28(S)	21(S)	20(S)	27(S)	18(S)	22(S)	15(S)	/(R)	10(R)
23	38(S)	21(S)	40(S)	30(S)	23(S)	24(S)	33(S)	20(S)	18(I)	22(S)	8(R)	18(I)
24	22(S)	20(S)	31(S)	28(S)	24(S)	16(S)	28(S)	17(I)	24(S)	/(R)	10(R)	18(I)
25	27(S)	19(S)	20(S)	27(S)	20(S)	20(S)	27(S)	16(I)	21(S)	13(I)	8(R)	10(R)
26	29(S)	21(S)	31(S)	25(S)	20(S)	22(S)	32(S)	20(S)	24(S)	16(S)	/(R)	11(R)
27	24(S)	27(S)	27(S)	30(S)	25(S)	17(S)	/(R)	18(S)	/(R)	12(I)	/(R)	10(R)
28	26(S)	18(S)	28(S)	26(S)	18(S)	20(S)	28(S)	16(I)	15(I)	13(I)	9(R)	14(R)
29	23(S)	20(S)	30(S)	26(S)	28(S)	17(S)	22(S)	20(S)	25(S)	15(S)	/(R)	10(R)
30	20(S)	19(S)	27(S)	27(S)	22(S)	18(S)	24(S)	17(I)	23(S)	16(S)	10(R)	13(R)
31	24(S)	21(S)	25(S)	28(S)	25(S)	22(S)	33(S)	18(S)	23(S)	16(S)	/(R)	9(R)
32	17(S)	17(S)	17(I)	27(S)	26(S)	19(S)	29(S)	20(S)	23(S)	15(S)	/(R)	11(R)
33	21(S)	18(S)	25(S)	29(S)	30(S)	19(S)	27(S)	19(S)	24(S)	16(S)	11(R)	10(R)
34	21(S)	20(S)	24(S)	26(S)	20(S)	19(S)	29(S)	17(I)	15(I)	14(I)	/(R)	11(R)
35	26(S)	19(S)	27(S)	23(S)	21(S)	18(S)	26(S)	19(S)	20(S)	13(I)	/(R)	12(R)
36	28(S)	22(S)	31(S)	28(S)	23(S)	21(S)	29(S)	20(S)	16(I)	15(S)	/(R)	9(R)
37	31(S)	21(S)	35(S)	/(R)	12(R)	10(R)	/(R)	22(S)	/(R)	12(I)	/(R)	14(R)
38	19(S)	24(S)	31(S)	25(S)	24(S)	15(S)	28(S)	18(S)	22(S)	14(I)	15(I)	11(R)

No.	Antibiotics											
	NOR	AKN	CIP	CMP	AMP	GEN	SXT	KAN	TET	STR	P-G	RIF
39	20(S)	20(S)	27(S)	23(S)	20(S)	20(S)	29(S)	19(S)	17(I)	15(S)	/(R)	10(R)
40	26(S)	18(S)	28(S)	26(S)	19(S)	20(S)	26(S)	16(I)	20(S)	15(S)	/(R)	10(R)
41	24(S)	19(S)	27(S)	20(S)	19(S)	20(S)	22(S)	17(S)	20(S)	14(I)	/(R)	11(R)
42	29(S)	20(S)	30(S)	26(S)	20(S)	20(S)	27(S)	18(S)	15(I)	14(I)	/(R)	10(R)
43	31(S)	28(S)	35(S)	25(S)	25(S)	25(S)	32(S)	23(S)	26(S)	18(S)	9(R)	13(R)
44	25(S)	19(S)	27(S)	25(S)	23(S)	19(S)	27(S)	18(S)	17(I)	13(I)	/(R)	10(R)
45	21(S)	17(S)	28(S)	29(S)	30(S)	19(S)	27(S)	19(S)	24(S)	16(S)	/(R)	10(R)
46	27(S)	20(S)	29(S)	29(S)	21(S)	21(S)	28(S)	18(S)	15(I)	14(I)	10(R)	13(R)
47	28(S)	19(S)	31(S)	25(S)	21(S)	21(S)	27(S)	18(S)	22(S)	17(S)	8(R)	9(R)
48	25(S)	20(S)	27(S)	23(S)	20(S)	21(S)	26(S)	18(S)	19(S)	15(S)	/(R)	10(R)
49	26(S)	21(S)	28(S)	20(S)	17(S)	22(S)	26(S)	18(S)	15(I)	15(S)	/(R)	10(R)
50	22(S)	20(S)	29(S)	24(S)	20(S)	20(S)	28(S)	7(R)	19(S)	14(I)	/(R)	9(R)
51	27(S)	18(S)	28(S)	27(S)	21(S)	20(S)	27(S)	17(I)	21(S)	12(I)	/(R)	10(R)
52	33(S)	18(S)	35(S)	27(S)	21(S)	20(S)	16(S)	17(I)	21(S)	14(I)	12(I)	10(R)
53	25(S)	18(S)	28(S)	26(S)	22(S)	20(S)	26(S)	18(S)	20(S)	13(I)	/(R)	11(R)
54	22(S)	29(S)	29(S)	35(S)	27(S)	19(S)	25(S)	15(I)	25(S)	17(S)	/(R)	12(R)
55	21(S)	21(S)	29(S)	25(S)	21(S)	20(S)	28(S)	18(S)	20(S)	9(R)	/(R)	9(R)
56	28(S)	17(S)	33(S)	25(S)	20(S)	20(S)	30(S)	18(S)	21(S)	13(I)	15(I)	9(R)
57	26(S)	20(S)	28(S)	23(S)	22(S)	21(S)	24(S)	18(S)	18(I)	15(S)	14(I)	11(R)
58	28(S)	20(S)	30(S)	26(S)	22(S)	19(S)	24(S)	18(S)	22(S)	14(I)	14(I)	9(R)
59	27(S)	19(S)	28(S)	26(S)	21(S)	20(S)	25(S)	17(I)	15(I)	17(S)	/(R)	10(R)
60	22(S)	17(S)	25(S)	22(S)	17(S)	19(S)	26(S)	15(I)	19(S)	13(I)	/(R)	11(R)
61	27(S)	20(S)	31(S)	28(S)	22(S)	21(S)	26(S)	18(S)	21(S)	13(I)	/(R)	11(R)
62	35(S)	20(S)	38(S)	28(S)	22(S)	21(S)	30(S)	18(S)	20(S)	15(S)	14(I)	11(R)
63	22(S)	21(S)	24(S)	37(S)	21(S)	20(S)	30(S)	20(S)	20(S)	13(I)	/(R)	14(R)
64	28(S)	23(S)	31(S)	26(S)	28(S)	25(S)	26(S)	20(S)	24(S)	17(S)	12(I)	11(R)
65	26(S)	21(S)	26(S)	24(S)	20(S)	18(S)	27(S)	16(I)	20(S)	13(I)	18(I)	12(R)
66	23(S)	19(S)	22(S)	21(S)	20(S)	19(S)	26(S)	16(I)	20(S)	13(I)	/(R)	11(R)
67	22(S)	19(S)	23(S)	24(S)	22(S)	19(S)	26(S)	17(I)	/(R)	10(R)	/(R)	11(R)
68	24(S)	21(S)	27(S)	30(S)	26(S)	21(S)	30(S)	19(S)	19(S)	14(I)	/(R)	10(R)

S = susceptible; I = intermediate; R = resistant.

Serological survey on infectious diseases of a White yak herd in the Gansu Province

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Summary

From a 330 head White yak herd, 50 (approximately 15%) blood samples for serum preparation were taken to determine the immune status of the animals in relation to viral and bacterial antigens. Viral antigens—Bovine Herpes Virus 1 (BHV1), Bovine Viral Diarrhoea/Mucosal Disease (BVD/MD), Parainfluenza 3 (PI3) and Bovine Leucosis (BLV)—the most important infectious diseases of cattle, were used. To determine typical bovine bacterial antibodies, the following antigens were used: *Brucella* spp., *Chlamydia* spp., *Coxiella burnetii*, *Salmonella* spp. and *Paratuberculosis*. Negative results were obtained for *Bovine Leucosis*, *Brucella* spp., *Salmonella* spp. and *Paratuberculosis*. A positive antibody status was demonstrated in 96% of the samples for PI3, 34% for BHV1, 18% for BVD/MD, 24% for *Chlamydia* and 2% for *Coxiella burnetii*. Surprisingly, the herd seemed to be negative for *Brucella* spp, which is quite common in yak and humans in the Himalayas. The proportion of positive cases for BHV1 and PI3 were comparable to cattle in other regions of the world. The incidence of *Chlamydia* was relatively high. Compared to cattle in other countries of intensive breeding where the proportion of positive BVD/MD are in the range of 70–80%, on average, the 18% positive animals in the present study was quite low.

Keywords: Serological survey, viral and bacterial antigens, White yak

Introduction

Serological procedures constitute an important basic methodology for the study of viral and bacterial diseases and of their causal agents. A number of studies on parasitic diseases have been conducted on the yak (Joshi and Pradhan 1977; Biwas et al. 1994; Liu 1994; Rangarao et al. 1994; Jiang et al. 1997), but the references on viral and bacterial diseases are very limited and even these do not have local experimental data, but are citations of results from elsewhere (Joshi 1976; Joshi et al. 1997; Lensch and Geilhausen 1997). Even the standard books on yak from Zhang (1989) and Cai (1990) do not refer to infectious diseases. The handbook of Lensch (1996) contains a short survey on parasitic infestations and infectious diseases of viral and bacterial origin.

This paper reports results of physical examination of blood serum samples from White yak with a focus on viral and bacterial antigens, which are common in bovine species.

Materials and methods

Animals, sample collection and preparation

From a 330 head White Yak herd in Tianzhu County (Gansu Province, P.R. China), 50 blood samples (approximately 15%) were randomly taken by venapuncture under aseptic conditions. The animals were of different ages and both males and females were represented.

After blood clotting at 4°C the samples were centrifuged for 10 minutes at 3000 rpm for serum preparation. The serum samples were stored in plastic tubes at -20°C until analysis.

Antigens

Viruses and bacteria were used as test antigens, following procedures routinely applied in a German diagnostic laboratory for bovine serum samples. Specifically viral antigens Bovine Herpes Virus 1 (BHV1), causing Infectious Bovine Rhinotracheitis (IBR) and Infectious Pustular Vulvovaginitis (IPV), Bovine Viral Diarrhoea/Mucosal Disease (BVD/MD), Parainfluenza 3 (PI3) and Bovine Leucosis (BLV), were used. To determine typical bovine bacterial antibodies *Brucella* spp., *Chlamydia* spp., *Coxiella burnetii* (causing Q (query) fever in ruminants and human), *Salmonella* spp. and *Paratuberculosis* were used.

Test methods

To detect positive antibody levels, depending on the antigens, different techniques were used. Enzyme Immune Assays (EIA) were applied to determine antibodies against BHV1, BVD/MD and *Coxiella burnetii*; Slow Agglutination Test (SAT) was used for *Brucella* and *Salmonella* spp. Serum Neutralisation Test (SNT) was used to detect Parainfluenza 3, Agar Gel Immune Diffusion (AGID) for BVL and Complement Fixation Test (CFT) for *Chlamydia*.

Results and discussion

Four of nine bovine antigens involved in the survey, *Bovine Leucosis*, *Brucella* spp., *Salmonella* spp. and *Paratuberculosis* (Johnes Disease), did not show any positive antibody levels. The results are summarised in Table 1.

A positive antibody status could be demonstrated in 96% of the samples for PI3, 34% for BHV1, 18% for BVD/MD, 24% for *Chlamydia* and 2% for *Coxiella burnetii*.

Parainfluenza viruses are found worldwide in animals and humans. Under normal conditions, PI3 infections in bovine species are clinically unapparent. They play an important role in USA and Europe as key agents of Shipping Fever and Crowding Disease within the so-called 'Bovine Respiratory Disease (BRD) complex'. The BRD complex is a

factorial disease and occurs particularly when animals are in stress situations, e.g. during transportation and crowding. Rolle and Mayr (1978) reported positive titres of PI3 in 60–90% of cattle in USA and Europe. Similar values could be observed in humans.

Table 1. Results of the serological survey.

Antigens ¹	Positive		Negative		Suspicious		Not analysable	
	No.	%	No.	%	No.	%	No.	%
BHV1	17	34	32	64	1	2	0	0
BVD/MD	9	18	38	76	3	6	0	0
PI3	48	96	0	0	2	4	0	0
Bovine Leukosis	0	0	50	100	0	0	0	0
Brucella	0	0	50	100	0	0	0	0
Chlamydia	12	24	34	68	1	2	3	6
Coxiella burnetii	1	2	49	98	0	0	0	0
Salmonella	0	0	50	100	0	0	0	0
Paratuberculosis	0	0	50	100	0	0	0	0

1. BHV1= Bovine Herpes Virus 1; BVD/MD= Bovine Viral Diarrhoea/Mucosal Disease; PI3= Parainfluenza 3.

The positive percentage of 34% for BHV1 seems comparable to cattle in other regions of the world. Although IBR/IPV is a separate disease clinically, the infection is very frequently associated with the BRD complex.

Compared to cattle populations in other countries with intensive management where the incidences of BVD/MD are 70–80%, on average, the 18% incidence in the present study was low. For western Germany, as far back as 1964, up to 72% of the cattle examined showed positive BVD/MD titres (Rolle and Mayr 1978).

The incidence rate (24%) for *Chlamydia* was relatively high. However, there were no figures available in literature, except personal communications, on the incidence of Chlamydia infections in the yak. As in cattle and other species, the focus in yak seems to be the genital tract. The infection affects conception/nidation and can cause enzootic abortions in yak.

The finding of a clearly positive reaction in one animal for *Coxiella burnetii*, a rickettial infection, which is tick-borne and is the causal agent of Q fever in ruminants and humans, was interesting.

It was, however, surprising that the herd was negative for *Brucella* spp., which is usually common in yak and humans in the Himalayan region. Detailed survey of Brucellosis cases in various animal species were carried out in Nepal (Joshi 1976; Payakural and Mishra 1977). Up to 29% positive reactions were observed in yak and yak hybrids. Brucellosis has also been confirmed in yak in the former Soviet Union (Schley 1967). Anon (1965) demonstrated the problems of Brucellosis as zoo-anthroponosis in Mongolia. In human populations with contact to a yak herd, 50–70% of the tested persons showed a positive reaction for *Brucella* spp.

From the results of the serological survey of the White yak herd in Tianzhu, mainly respiratory and, to some extent, genital infections seem to play a significant role. However, it

must be emphasised that a single study such as this provides only a snapshot at a point in time and shows only the situation of the day the serum samples were taken. To assess the real situation, at least two serum samples, taken 3–4 weeks apart, have to be analysed to determine sero-conversion.

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Treatment of bovine mastitis with medicinal herbs and acupuncture

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Summary

Mastitis is the most common disease in dairy cows. Widespread use of antibiotics for the treatment of this disease has a potential to cause contamination of milk, which has become a subject of public concern. Medicinal herbs and acupuncture are natural and safe approaches, and are receiving attention from an increasing number of veterinarians. Based on clinical signs and manifestations, mastitis is usually classified into three patterns: domination of 'heat pathogen', stagnation of Qi and blood, and deficiency of Qi and blood. Four herbal prescriptions for the treatment of different patterns of bovine mastitis are described. They are Powder of Dandelion, Decoction of Snakegourd and Burdock Achene, Ease Powder, and Decoction of Eight Precious Ingredients. Laser-acupuncture therapy is also introduced.

Keywords: Acupuncture, cows, herbal medicine, mastitis

Introduction

Mastitis is the most common disease in dairy cows, which accounts for a great deal of economic loss throughout the world. The common practice in China is the intramammary infusion of antibiotics when clinical mastitis is detected. Due to the extensive use of antibiotics in dairy herds, contamination of milk has become a subject of public concern. Therefore, an increasing number of veterinarians are turning to non-antibiotic approaches in order to reduce the use of antibiotics. In the traditional Chinese veterinary medicine, only medicinal herbs and acupuncture are used to treat animal diseases. These are believed to be natural and safe therapeutic methods. In this paper, four commonly used prescriptions and a laser-acupuncture therapy for mastitis treatment are described.

Patterns of mastitis and therapeutic principles

In the traditional Chinese veterinary medicine, therapeutic method is chosen based on the identification of disease patterns. Mastitis is usually classified into three patterns according to the clinical signs and manifestations (Kang 1991).

The pattern of domination of heat pathogen

This pattern is characterised by red, swollen, heat and painfully inflamed quarter with decreased milk production, and abnormal secretion in the gland. The cow may appear lame because inflammation of the gland causes her to walk awkwardly in an attempt to avoid leg-udder contact. Severely affected cows may show systemic illness such as high fever, depression, loss of appetite, dry mouth, condensed urine and rapid pulse. This condition is believed to be caused by invasion of 'heat pathogen' into the mammary gland due to the traumatic teats or udder, resulting in galactostasis, and damage of the duct system. The pattern corresponds to acute mastitis. The therapeutic principle for containing the condition is to eliminate 'heat pathogen' and subdue swelling.

The pattern of stagnation of Qi and blood

This pattern has no systemic changes, and the changes in the gland and secretion are less marked. There are hard lumps in the udder, which can be detected by palpation, and milk production is reduced. The condition is believed to be caused by stagnation of Qi and blood in the udder due to poor management or mental disorder in the animals. In the doctrine of the traditional Chinese veterinary medicine, a liver-channel and a stomach-channel are said to pass through the udder and teats. The normal flow of Qi and blood in the channels is necessary for the normal function of the mammary gland, and stagnation of Qi and blood in the channels will lead to dysfunction of milk secretion and give rise to mastitis. This pattern corresponds to sub-acute mastitis. The therapeutic principle here is to dredge the liver channel and disperse the lumps.

The pattern of deficiency of Qi and blood

In this pattern, systemic changes, and the changes in the gland are not obvious, but the milk frequently becomes abnormal. The affected animals may appear emaciated, lassitude with thin and lightly coloured coating on the tongue etc. This pattern of mastitis is thought to be a result of deficiency of Qi and blood due to malnutrition or other chronic diseases. Milk is considered to be transformed from Qi and blood, deficiency of which may lead to insufficient milk production and cause mastitis. Some subclinical cases belong to this category. The therapeutic principle in this case is to supplement Qi and blood.

Therapeutic methods

Pattern of domination of heat pathogen

The treatment includes oral administration of Powder of Dandelion (Wei 1987). One dose of the powder consists 250 g of *Herba taraxaci*, 100 g of *Flos lonicerae*, 75 g of *Fructus forsythiae*, 50 g of *Fructus retinervis luffae*, 25 g of *Medulla tetrapanacis*, 25 g of *Flos hibisci* and 30 g of

Squama manitis. These herbs are ground into powder and orally administered after mixing with boiled water. A good result can also be obtained from oral administration of Decoction of Snakegourd and Burdock Achene (Institute of Traditional Chinese Veterinary Medicine and Institute of Veterinary Medicine of Chinese Academy of Agricultural Sciences 1979). One dose of the decoction contains 30 g of *Fructus trichosanthis*, 24 g of *Fructus arctii*, 18 g of *Radix bupleuri*, 30 g of *Radix trichosanthis*, 30 g of *Fructus forsythiae*, 30 g of *Flos lonicerae*, 24 g of *Radix scutellariae*, 15 g of *Pericarpium citri reticulatae*, 24 g of *Fructus gardeniae*, 60 g of *Herba taraxaci*, 24 g of *Radix glycyrrhizae* and 15 g of *Pericarpium citri reticulatae virida*. The herbs are decocted in boiling water and the soup is orally administered after cooling.

Pattern of stagnation of Qi and blood

Oral administration of Ease Powder is recommended for this pattern (Kang 1991). One dose of the powder consists of 30 g each of *Radix bupleuri*, *Radix angelicae sinensis*, *Radix paeoniae alba* and *Rhizoma atractylodis macrocephalae*; 20 g each of *Poria*, *Radix glycyrrhizae praeparatae* and *Rhizoma zingiberis praeparatae*; and 15 g of *Herba menthae*. These herbs are ground into powder and orally administered after mixing with boiled water.

Pattern of deficiency of Qi and blood

The treatment includes oral administration of Decoction of Eight Precious Ingredients (Wei 1987). One dose of the powder consists 30 g of *Radix ginseng*, 40 g of *Rhizoma atractylodis macrocephalae*, 40 g of *Poria*, 30 g of *Radix glycyrrhizae*, 50 g of *Radix angelicae sinensis*, 50 g of *Radix paeoniae rubra*, 40 g of *Rhizoma ligustici chuanxiong*, and 40 g of *Rhizoma rehmanniae praeparatae*. These herbs are boiled in water and orally administered after cooling. Subcutaneous injection of *ginseng* extract may activate immunocompetent cells and increase the body resistance against intramammary infection (Hu et al. 2000).

Acupuncture treatment

Besides the administration of the herbal prescriptions mentioned above, it is recommended to stimulate Acupoints Yang Ming with a He-Ne laser beam to promote recovery from mastitis (Figure 1) (Kang 1991).

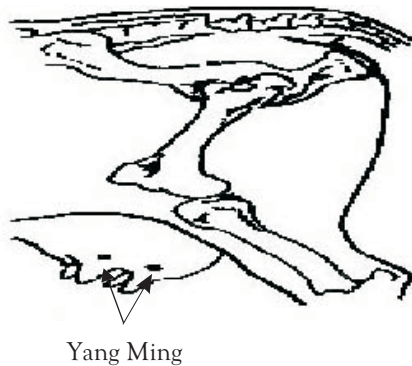


Figure 1. Acupoints Yang Ming of the dairy cow.

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Mastitis control in ruminants

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Summary

Mastitis is a multifactorial and costly problem worldwide and can occur in all milk-producing ruminants. It affects not only animal welfare, but will also result in decreased milk production and deterioration of the milk quality. A healthy mammary gland is a result of a complex balance between the cow, the micro-organisms and the environment. Decreased disease resistance in the cow, increased virulence of the micro-organisms or increased burden from the environment will result in mastitis. Mastitis can be difficult to treat successfully. Therefore, it is important to identify risk factors in order to be able to prevent the disease from occurring. It is important to make the farmer aware of the problem, and to make him/her understand the importance of good management and environment. In many countries some kind of control plan is recommended. The yak is an important source of milk for millions of people in Asia even though the production per cow is low. So far, there are few reports on mastitis in yak. Whether this is due to a high resistance against infections in the mammary gland, or to a lack of investigation into the problem, is not clear. Crossbreeding of yak with high-producing breeds will increase the milk production, and the risk for mastitis. Therefore, it is important to increase the knowledge about mastitis in yak and the risk factors involved in yak milk production. In this paper, the etiology of mastitis is discussed, together with predisposing factors such as housing, feeding, genetics and milking, as well as ways to control the disease.

Keywords: Control, etiology, mastitis, predisposing factors, ruminants, yak

Introduction

Mastitis is a multifactorial and costly problem, which occur in all milk-producing ruminants. It affects animal welfare and results in decreased milk production and deterioration of the milk quality. Mastitis is a common problem in most countries with dairy production. In Sweden 18% of the dairy cows are treated by veterinarians each year for clinical mastitis. However, a large number of mastitis cases are subclinical and can only be detected by high milk somatic cell counts (SCC). The yearly incidence of all cases of mastitis in Sweden (both subclinical and clinical) is estimated to be around 64% (Svensk Mjök 1999). The major costs involved are decreased milk production and increased culling of animals. Current programmes for control of bovine mastitis have improved the situation substantially, but the incidence of clinical and subclinical mastitis is still high.

Mastitis can be difficult to treat successfully. Therefore, it is important to understand the underlying mechanisms and to identify risk factors in order to prevent the disease. It is also important to make the farmers aware of the problem and the importance of good management.

The yak is an important source of milk and other products for millions of people in Asia even though the milk production per cow is low. However, crossbreeding with cattle breeds with a higher production has become more common (Joshi et al. 1994; Rongchang et al. 1994). As a result the milk production increases, and thereby also the risk for mastitis. So far, there are few reports on mastitis in yak and yak hybrids. Whether this is due to a high resistance against infections in the mammary gland, or to a lack of investigations, is not clear. With increasing production and the introduction of milking machines, it is important to increase the knowledge about mastitis and the risk factors involved in yak milk production.

Etiology of mastitis

Mastitis means inflammation of the mammary gland and is an important defence reaction of the body to a local damage. Pre-inflammatory damage to the udder is most often due to some kind of trauma, bacterial toxins, or a combination of trauma and bacterial infections. The risk for such damages is influenced by predisposing factors in the cow, environment and/or management.

Most cases of mastitis are associated with bacterial udder infections. The most common mastitis pathogens are different staphylococci (*Staphylococcus aureus* and coagulase negative staphylococci) and streptococci (*Streptococcus agalactiae*, *Streptococcus dysgalactiae* and *Streptococcus uberis*). Other important bacteria are coliforms like *Escherichia coli* and *Klebsiella* spp. The route of infection is almost always via the teat canal.

A healthy mammary gland is a result of a complex balance between the cow, the micro-organisms and the environment. Decreased disease resistance in the cow, increased virulence of the micro-organisms or increased burden from the environment will result in a disturbance of the balance, which can result in mastitis. The balance is affected by many factors, which predispose for damage and udder infections by reducing the immune defence of the cow or increase the risk for infections in different ways.

Predisposing factors

Factors predisposing for udder infections and mastitis can be genetic or environmental. Examples of such factors in the cow are breed, age, milk production, teat and udder shape, temperament and genetic potential for milk production. Other cow factors, like viral infections, ectoparasites, claw health, lactation stage and immune status can also be of importance. Likewise, there are a number of factors in the environment and management that can predispose for disease. Such examples can be found in the climate, housing, feeding, and in milking routines and equipment. Some of these factors will be highlighted below.

Some cow factors

The immunological status of the animal will affect the risk for disease. During certain stressful periods, e.g. around calving, the immune functions of the dairy animal are suppressed (Sordillo et al. 1997; Mallard et al. 1998). This period, i.e. the peri-partum and early lactation period, is associated with a high susceptibility to udder infections and mastitis (Sordillo et al. 1997). High blood levels of glucocorticoids, as well as of other hormones, are present around parturition, and the risk for metabolic stress is high. Examples of stress factors during this period are parturition, onset of lactation, and changes in feeding and management regimes. Other diseases, like different viral infections, can also cause immune suppression, which increases the risk for other health problems like mastitis (Niskanen et al. 1995). Local stress due to injuries to, or various skin diseases of, the teats and udder is also an important risk factor for udder infections.

Research on genetic resistance against udder infections and mastitis is important. However, heritability of clinical mastitis has been estimated to be low (Emanuelson et al. 1988; de Haas 1998). The SCC, as an indirect measurement of mastitis, has a higher heritability, and might be a better selective tool than clinical mastitis (Emanuelson et al. 1988; de Haas 1998). A combination of these parameters is recommended for selection towards reduced susceptibility to mastitis. Philipsson et al. (1995) reported a linear relationship between sires' breeding values for clinical mastitis and for SCC.

High milk production and various udder traits, such as udder suspensory ligament, fore udder attachment and udder depth, are associated with increased incidence of mastitis (Uribe et al. 1995; Alexandersson 1998; Emanuelson et al. 1988). A similar relationship was observed between mastitis traits and milk protein production (de Haas 1998).

In the Nordic countries, udder traits, cell counts and clinical mastitis are included in the breeding values of bulls in order to improve disease resistance. Other countries have recently started to include mastitis selection parameters in the breeding programs.

Climate

Most literature deals with heat stress and its detrimental effect on milk production. However, some studies also address the effects of heat on immune functions and udder health. Exposure of cattle to high temperature can increase the stress of the animal (Johnson and Vanjonack 1975). The total cell counts in both blood and milk were higher in heat stressed cows (Webster 1983; Elvinger et al. 1991). The results also indicated that heat stress depresses leukocyte responses *in vitro* (Elvinger et al. 1991), and migration of leukocytes into the mammary gland (Elvinger et al. 1992). However, Paape et al. (1972) did not observe any increase in the SCC due to thermal stress.

There are few studies on the effects of cold stress on mammary gland immunity, but it is well recognised that cold conditions can cause damages to the teat skin, especially when the teats are wet after milking and teat dipping. This will increase the risk for bacterial infections.

Housing/management

Different housing systems may be associated with a variety of risk factors. In free-stall systems the design and management of the cubicles is essential. If the cubicles are not comfortable the cows will not use them but lie down elsewhere. Likewise, special risk factors are present when using pasture, a straw yard or a sand yard, and if a tie-up system is used where the cows have limited ability to move. In all housing systems, high stocking density, dirty bedding or ground, and high humidity are important risk factors. Housing and poor hygiene are associated with a higher risk for both clinical (Barkema et al. 1999) and subclinical mastitis (Ekman 1998). The feeding environment is also important. All cows must be allowed equal access to both feed and water.

The farmer

The attitudes and actions of the farmer are essential in order to keep disease to a minimum. The importance of management has been shown in several studies. For example, Ekman (1998) showed that low bulk milk SCC was associated with having clean cows that were well clipped with trimmed claws. Other significant factors were that the farmer was a patient, confident and sufficiently considerate person who also liked cows. The importance of an early detection of problems/diseases by the farmer/milker is obvious, and is the prerequisite for good health and welfare of the animals.

Milking

The milking procedure is one of the most important risk factors for both clinical mastitis and high SCC (Ekman 1998; Barkema et al. 1999). Malfunctioning machine milking can induce damage to the teat tissue increasing the risk for udder infections. Examples of risk factors are faulty vacuum level, pulsation rate and ratio, and liner design (IDF 1994). The milking routine is also very important. It is essential that the milking be performed in a hygienic way, in a calm environment and with the same routine each time. It is important to identify cows, which have mastitis. These cows should be milked last, or separately, to avoid spread of bacteria among animals.

Stress can lead to milk retention by inhibiting oxytocin-mediated reflexes (McCaughan and Malecki 1981; Johansson 2000). New environment, new milkers, painful milking technique and pain due to udder oedema are factors, which can be stressful for the animal. Inhibition of milk-let-down can cause subclinical mastitis to become clinical and will affect milk production.

Feeding

Adequate nutrition is essential for overall health and the ability of the animal to resist diseases. The balance between protein and energy, supplementation of micronutrients, and

feeding routines are factors influencing animal health by potentially increasing the risk for metabolic disturbances. Also, the hygienic quality of the ration is important.

At the onset of lactation dairy cows are metabolically stressed due to negative energy balance leading to the mobilisation of considerable amounts of tissue reserves. This could also be associated with the increased incidence of infectious diseases during this time. Increased levels of ketone bodies can have a negative effect on immune functions and influence the severity of mastitis (Klucinski et al. 1988; Kremer et al. 1993; Hoeben et al. 1997).

A balanced supply of micronutrients (vitamins, minerals and trace elements) is essential during periods of immune suppression. Deficiencies in selenium (Se), vitamin E, vitamin A, copper (Cu) and zinc (Zn) have been associated with a negative influence on the immune response in association with mastitis (Reddy and Frey 1990; Harmon and Torre 1994; Smith et al. 1997). If the contents of such minerals as Se, Cu and Zn are low in soils and pastures, supplementation may be necessary. Likewise, dietary supplementation of vitamin E and A may be necessary as the concentration in fodder decreases with length of storage.

Mastitis control

Mastitis can be rather difficult to treat efficiently. Antibiotics are used in various ways, but with limited success, for example due to the development of resistance against antibiotics. Therefore, it is important to find means to prevent the disease as well as have a plan for handling cases of mastitis when they occur. In many countries some kind of mastitis control programme has been adopted. To make these programmes work it is essential that the farmer/milker understands the association between management and mastitis. It is also important to identify the problems on each herd and adjust the control programme for its specific needs.

A typical control programme will include a number of recommendations for good management in order to prevent the disease. In such a plan the following are important:

- good hygiene and management
- good milking technique
- regular checking of milking equipment
- correct milking order
- post milking teat dipping when needed
- prompt treatment of clinical cases
- dry cow therapy when needed
- culling of chronic cases.

Herd investigation

Most often mastitis is not a problem only in one cow of a herd. Commonly a herd problem, like high SCC, can be observed. In order to find the best control plan for each herd, it is necessary to do a thorough herd investigation to identify its specific problems. To make a

correct diagnosis of the herd the management has to be carefully studied and problem cows must be identified. It is of great benefit to do bacteriological investigations of milk samples to further evaluate the problem. Depending on the bacteriological findings and the results from the herd investigation the udder health problems can often be identified as either due to cow specific or environmental bacteria. As these bacteria have a different pathogenesis the recommendations for herd control are also somewhat different.

Udder health problems caused by cow-specific bacteria, like *Staphylococcus aureus*, *Streptococcus dysgalactiae* and *Streptococcus agalactiae*, are often associated with problems at milking. These bacteria are transmitted between cows and udder quarters at milking, either by the milker or the milking machine. In contrast, environmental pathogens, like *E. coli*, *Klebsiella* spp and *Streptococcus uberis*, often infect the udder between milkings. Such udder health problems are often associated with bad hygiene.

Milk production and mastitis in yak

Milk production

The yak is very important for the local population, especially in remote and cold high-altitude areas. This is due to its many functions, production of milk, meat, hair/wool, leather and manure for heating, as well as transportation of both people and goods (Rongchang et al. 1994; Sasaki 1994).

Yak milk is consumed fresh or preserved in different ways, like cheese. In many areas, the milk is consumed locally, but in other areas yak milk products are an important source of income, and is, for example, sold to tourists. The milk production per yak cow is low and varies depending on feed, environmental conditions and season of calving. A typical lactation period would last for 100–150 days and produce 500–800 kg per lactation (Sasaki 1994; Long et al. 1999). However, the calf suckles most of the milk, so only about 1 kg/day is available for human consumption (Rongchang et al. 1994; Long et al. 1999). The yak is either milked once or twice per day. Milking twice a day increases both the daily production and the length of the lactation period but may not be recommended when the feed resources are poor (Long et al. 1999). The rear quarters have a higher production than the fore quarters (Xin and Luojun 1994). Milk let-down may not be elicited unless preceded by suckling and the calf is at foot (Xin and Luojun 1994). However, in the dzo (Yellow cattle × yak) cows, majority of cows could be hand milked without the calf or in the presence of the calf (Xin and Luojun 1994).

Milk production depends highly on feeding. Traditionally, yak depend on grazing and supplemental feeding is not given. During certain periods, underfeeding is common and this will influence milk production, reproductive performance and disease resistance. Long et al. (1999) showed that calving rates and live weight losses were influenced by whether grazing was done with or without supplements. Most yak only produce a calf every second year, but under good forage conditions they can produce a calf every year.

Crossbreeding of yak with different breeds of cattle has become popular in certain areas to increase milk production and to produce an animal that is more adapted to the

intermediate altitude zone. However, the hybrids cannot stand harsh environments as well as the purebred yak. The male hybrid is sterile but the female is fertile and can be crossed back to cattle or yak bulls (Joshi et al. 1994; Rongchang et al. 1994). The crosses have a substantially higher daily milk production and their lactation period is longer. Moreover, they often produce a calf each year.

Mastitis

To my knowledge limited information is available about the incidence of mastitis in purebred and crossbred yak. According to Xin and LuoJun (1994), streptococcal mastitis has been reported in yak in China. In one study, 4 out of 40 yak (10%) had subclinical mastitis, as measured by the SCC (Ma 1987). In another study, 224 yak in 4 counties in Hainai were investigated (Tang and Cai 1990). According to the SCC, 3.6% of the yak and 1.6% of the quarters had subclinical mastitis. The results differed somewhat between counties and the number of cases seemed to increase with lactation number. Bacteriological investigations were not performed in either study.

Final remarks

In order to avoid mastitis and its costs in milk producing animals it is important to identify risk factors that can negatively influence the defence mechanisms of the mammary gland. The importance of good management and adequate nutrition for the prevention of mastitis are some factors to consider. The possibilities for genetic selection of individuals with a well-developed resistance against udder infections and mastitis could also be evaluated.

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A diagnosis study of brucellosis and *Chlamydia* infection in yak

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Summary

Following extended S₂ vaccine inoculation in yak, a diagnosis study including serum agglutination test (SAT) for brucellosis and indirect haemagglutination (IHA) for *Chlamydia* infection was conducted using 526 serum samples from un-inoculated yak calves over 8 months old in the area covered by the vaccination programme. There was only one positive serum sample in SAT but 15 positive serum samples in IHA. The results showed that brucellosis had been successfully controlled, but that *Chlamydia* infection was still prevalent and, hence was responsible for the prevailing cases of abortion in yak in the area. Attention is needed for the control of these *Chlamydia*-caused abortions.

Keywords: Brucellosis, *Chlamydia*, diagnosis, yak

Introduction

In historic records the serum positive rate of brucellosis in yak from the Xinghai County of Hainan Prefecture of Qinghai Province, where both brucellosis and *Chlamydia infection* were prevalent, was 31.19%. Since 1982, a yak vaccination project was conducted by S₂ vaccine and a total of 200 thousand doses of vaccines were administered on the same number of animals. This study was conducted in 1996 to evaluate the effectiveness of the programme and examine the epidemiology of *Chlamydia* infection in yak.

Materials and methods

Serum samples

Five hundred and twenty six samples for test were collected from un-inoculated yak calves over 8 months old in the area where the S₂ vaccination programme had been implemented.

Diagnosis reagents

The antigen, positive and negative control serums for brucellosis were provided by the Chendu Biological Manufacture, P.R. China. Diluting solution used in SAT was 0.9%

NaCl. Antigen, positive and negative control serums, and their diluting solution were produced by the Lanzhou Veterinary Institute of the Chinese Academy of Agricultural Sciences.

Index for evaluating the results

For brucellosis in SAT, the index used was following the requirement in the regulation promulgated by the Ministry of Agriculture (1979). For *Chlamydia* infection in IHA, the index was as described by the manufacture. 96-V holes micro-plates were chosen for IHA. When 2 crosses (++) were shown in 1:16 titre (50% or up of the red cells was evenly distributed at the low part of the holes), this was considered as positive. When 2 crosses (++) or less were shown in 1:4 titration, this was treated as negative. For both the SAT and IHA, there were positive and negative duplication controls, respectively.

Results and discussion

From Table 1, it can be seen that the positive rate of brucellosis is 0.19%, which is much lower than the 31.19% recorded in 1981 before the vaccination programme was implemented (300/982, $P < 0.01$). These results show that the S₂ vaccine inoculation project was quite successful and resulted in the control of brucellosis in yak in the study area. However, the proportion of positive cases of *Chlamydia* infection is up to 2.85%, which indicate that it should continue to receive attention because both brucellosis and *Chlamydia* infection are important pathogens responsible for abortion in yak in the study area. Yak is an important animal in this area, and abortions represent an important production constraint, which needs to be addressed. Current attention should be focused on abortions resulting from the *Chlamydia* infections.

Table 1. Diagnosis results of brucellosis (SAT) and *Chlamydia* (IHA).

Method	Samples	Positive	Percentage
SAT	526	1	0.19
IHA	526	15	2.85

Effect of Japanese Kampo Medicines on *in vitro* preservation of bovine spermatozoa and *in vitro* fertilisation

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Summary

In this experiment, the potentials of four kinds of Japanese Kampo Medicines (JKMs), *syohangekabukuryoto*, *hotyuekkito*, *ogikentyuto*, *ninjin-eiyoto* and mixed JKMs to improve physiological function of frozen-thawed bovine sperm motility when semen samples were incubated for 22 h at 37°C in medium 199 supplemented with JKMs were investigated. Following the experiment, *in vitro* fertilisation (IVF) and subsequent embryonic development of bovine oocytes treated with JKMs-processed sperm were examined. Results show that some of the JKMs slightly improve motility of frozen-thawed bovine spermatozoa and increase IVF rate. Slightly increased percentage of IVF was also observed by adding the JKMs to the medium phosphate buffered saline (PBS).

Keywords: Bovine oocytes, *in vitro* fertilisation (IVF), Japanese Kampo Medicines (JKMs), sperm motility, wild animals

Introduction

It has been reported that endangered and/or extinct wild animals such as the giant panda, golden monkey and takin have very weak libido, which lead to lower rates of fertilisation and conception (Feng et al. 1997).

In our previous studies, the possibility of employing JKMs to improve frozen-thawed bovine sperm activity and to enhance *in vitro* fertilisation of cattle oocytes have been demonstrated (Zhao et al. 1997a; Zhao et al 1997b). On the other hand, one of the components of JKMs, frulic acid, has been shown to strongly stimulate human sperm activity *in vitro* (Zheng and Zhang 1996). These experimental results suggest possible enhancement of mammalian sperm activity by JKMs. Hitherto, most of the experiments with JKMs were carried out for curing human female infertility (Mizutani et al. 1988; Yamano et al. 1990).

Materials and methods

Preparation of JKMs

In this study, we used the following four sorts of JKMs, *syohangekabukuryoto*, *hotyuekkito*, *ogikentyuto*, *ninjin-eiyoto*, and mixed JKMs (Dongchongxiacao:Shaoyao:Guipi:Danggui:Huangqi:Gancao = 3:2:2:2:2:1). These JKMs were boiled for 1.5 hours to extract crude components and then filtered. The extracts were then diluted with PBS in a ratio of 1:10 and stored at 4°C.

Preparation of semen samples

Frozen bovine semen was thawed in a water bath at 37°C and washed twice in PBS by repeated centrifugation at 300 g for 5 minutes at room temperature (22–25°C). The precipitated sperm pellets were suspended in PBS to obtain a final concentration of 4×10^7 sperm cells/mL.

In the preliminary experiments, fresh semen and/or higher motile spermatozoa were shown not to be suitable for present experiments due to no difference in sperm activity between JKMs and control group. This observation suggested that JKMs should not be used for highly active spermatozoa but for slightly immotile sperm cells. To do this, sperm suspension was incubated in shaking water bath for 10 minutes at 46°C for leading to slightly faint spermatozoa.

In vitro maturation (IVM) of bovine oocytes

The ovaries obtained from cows at a local slaughterhouse were brought to the laboratory in warm (37°C) physiological saline (0.85% NaCl) within 2 h after collection. The cumulus-oocytes complexes (COCs) were collected from follicles 2 to 8 mm in diameter. COCs were washed twice in PBS and three times in maturation medium, which is 199 medium supplemented with 10% FCS, 1 µg/mL estradiol 17β and antibiotics. Approximately 15 to 20 COCs were introduced into a 100 µL drop of maturation medium in 35-mm petri-dishes under mineral oil. The oocytes were incubated at 39°C for 22 h under 5% CO₂ in air in the incubator.

In vitro fertilisation (IVF) of *in vitro*-cultured oocytes

The oocytes following IVM culture were washed three times in PBS and introduced into 100 µL drop containing 2 µL of sperm suspension, 10 µL JKMs solutions and cultured for 6 hours at 39°C in the same incubator as for the IVM.

***In vitro* culture (IVC) of fertilised oocytes**

After 6 h of culture for insemination, presumptive zygotes were washed twice in PBS and culture medium (199) containing 10% FCS and antibiotics. Fifteen to twenty zygotes were transferred into culture medium (100 μ L drop) and cultured for 36–48 h at 37°C in the CO₂ incubator. Following the culture, zygotes were washed twice in PBS to remove cumulus cells. Embryonic development was examined under a light microscope.

Results and discussion

Some of the JKMs slightly improved sperm motility and increased the rates of fertilisation. Similar results to this have been reported in cattle spermatozoa using other kinds of JKMs (Zhao et al. 1997b). However, much better results have been demonstrated in the cattle semen when proteinaceous substances such as fetal calf serum or cow serum were added to the medium. (Zhao et al. 1997a).

On the other hand, the JKMs used in our laboratory have been considered to be alternatives to the above-mentioned materials when these chemicals are expensive or difficult to obtain, especially in some Asian countries. In this experiment, special attention was also paid to the researches in China, regarding giant pandas and crested ibis, which are at present among the most critically endangered animals in the world.

In case of human spermatozoa, one of the most important components of JKMs, ferulic acid, has been reported to remove lipid peroxidatives as a scavenger, making it an effective factor for improving physiological function of spermatozoa (Cummins et al. 1994; Plante et al. 1994).

These series of experiments may also suggest the possibility of restoring impaired sperm function in human and animals by *in vivo* treatment. An interesting piece of research on JKMs would be the clarification of mechanism of physiological function of these medicinal herbs. This is planned for the future.

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The role of community animal health workers in an efficient animal health management system

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Summary

Veterinarians Without Borders Switzerland (VSF-CH) conducted, in 1999, an assessment of the Veterinary Services in the Autonomous Tibetan Yushu Prefecture, Qinghai, P.R. China. The goal of the mission was to evaluate the possibilities of a programme to support the animal health care services. The analysis indicates that the training and the activities of Community Animal Health Workers (CAHWs) need special attention. In large areas like the Himalayan highland, CAHWs make an important contribution to animal health care in the field. A strengthened animal health care programme can improve the economic situation of the rural population. Healthy animals have a good productivity and bear better the harsh highland winters.

Keywords: Community animal health workers (CAHWs), sheep, snow disaster, yak

Introduction

Winter disasters

In 1996 and 1998, Qinghai Province, P.R. China, especially its Yushu Tibetan Autonomous Prefecture, suffered extreme climatic conditions. The herdsmen lost a big part of their herds. About 1.5 million animals died in the area due to lack of fodder, large quantities of snow and extreme low temperatures. In spite of several programmes supported by governments, local and international organisations, the number of animals could not be restocked until spring of 1999. The economic situation of the rural population in the area is therefore still severe.

Chinese 4-set programme

In 1996, the Chinese Government initiated a development programme termed the '4-set programme' to try to assist farmers. The programme supports the construction of family houses and animal sheds, the fencing of selected areas as well as the improvement of grasslands. In spring 1999, already 25–35% of the farmers had the whole set realised. The

programme is ongoing. It represents an important step towards preventing future winter disasters.

Mission of VSF-CH

VSF-CH conducted an assessment of a future programme to support the veterinary services in the Yushu Tibetan Autonomous Prefecture, from March 29th to May 2nd, 1999 (Horber 1999). The goal of the mission was to evaluate in which form herdsmen might be assisted to prevent future winter disasters. Special attention was given to the animal health care services. Animal productivity has to be increased in order to improve and assure the family income. Key issues are: good reproduction rate, low animal losses, and adequate weight gain of animals on grasslands. These can only be achieved if animals are healthy. Healthy animals not only have a better productivity, but also bear better the harsh highland winters.

The veterinary services in Yushu

Staff

The veterinary service has a good hierarchically organised structure (prefecture> county>township>village>small team). It consists of 74 veterinarians, 172 veterinary assistants, 820 village doctors and 6000 small team prevention doctors. The group of the village doctors and small team prevention doctors is called in this paper 'Community Animal Health Workers' (CAHWs). Veterinarians and assistants have a university or college degree, whereas CAHWs are mostly herdsmen with very basic animal health training. CAHWs are working successfully not only in China, but also in other countries like for instance in The Sudan (UNICEF/OLS 1997) and in the Republic of Santo Domingo (PROMESA 1998).

Problems of health management system

- Purchase and financing of medicaments, drugs and vaccines;
- Transportation facilities (big area, large distances);
- Communication between veterinarians and herdsmen;
- Modest salary and difficult living conditions (climate, accommodation, shopping);
- Simple infrastructures (laboratories, storage rooms);
- Rudimentary training of CAHWs.

Community animal health workers

Qualification of CAHWs

CAHWs live closer to the rural population and the animals than veterinarians. In general they are highly respected villagers. That is why they may contribute efficiently to the animal

health management system in spite of their limited literacy. Veterinarians have much better knowledge of animal health care but they are rarely able to reach sick animals in time (distance, communication and transportation facilities, costs).

Strong points of CAHWs

- CAHWs live among the communities.
- CAHWs are mostly herdsmen themselves (or farmers' wives).
- CAHWs know best the needs of the rural population and their animals.

Weak points of CAHWs

- Lack of training (limited literacy, no training in animal health care);
- Lack of infrastructures (medicaments, equipment, adequate storage rooms, transportation facilities).

Activities of CAHWs

- Implement the animal disease prevention programmes (vaccination campaigns, prevention of parasitic diseases),
- Do simple treatments of sick animals,
- Advise herdsmen in general health care,
- Manage a small local stock of 8–10 medicaments
- Responsible for the communication with the veterinary service.

Training and supervision of CAHWs

The official veterinary service is responsible for the training, the necessary refresher courses and the supervision of the activities of the CAHWs.

Appointment of CAHWs

CAHWs are appointed and paid by the rural population in Yushu. This approach is recommended also for other similar services. The confidence of the population in their village doctor probably is the key to the success of the health service.

Financing of the local health care service

The sustainability of an efficient local animal health care service depends also on its financing model. In earlier times the service was free of cost. In the future, the beneficiaries will have to pay the costs of the local animal health care service. However, the level of

payments must take into account the income of farmers. It might be reasonable to establish a medicament revolving fund managed by the villagers. The introduction of a new economic model is delicate. The possibilities have to be discussed with the people. The application of the participatory rural appraisal (PRA) methodology might be helpful. The villagers have to take their own decisions and to fully carry the economic responsibility.

Conclusion and recommendations

In large areas with a low population density but an important livestock sector an efficient animal health care service is necessary. Only healthy animals have a good productivity and do bear the difficult climatic conditions on the Himalayan highlands.

CAHWs (village doctors and small team prevention doctors) are making an important contribution to animal health care in the field. They live close to the animals. Being themselves herdsmen, they know best the needs of their colleagues. The beneficiaries should pay the salary of the CAHWs and the local animal health care service, but prices must be realistic so that farmers can afford the service. CAHWs need to be trained and supervised by the veterinary officers. Each CAHW needs a kit with basic equipment (for example, syringe, needles, scissors) and 8–10 medicaments. The relevant instruction manuals have to be translated into the local language and, if necessary, illustrated.

Veterinarians are responsible for the implementation of the official animal health care management programme, especially the prevention of epizootic diseases. They train and supervise the CAHWs.

Careful purchase of medicaments, adequate medicament storage rooms, transportation and communication facilities for staff are important for a successful animal health care system.

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Test of enterotoxigenicity of *Escherichia (E) coli* isolated from yak

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Summary

Three strains of enterotoxigenic *E. coli* isolated from dead yak were cultured in improved Mundell medium and the resulting filtrates were collected. The ileum ligation test was done with adult rabbits and mice aged 1–3 days by infusing the filtrates. The results indicate that three strains of enterotoxigenic *E. coli* produce toxic agents. This may be the cause of diarrhoea and subsequent death of yak.

Keywords: Enterotoxigenicity, enterotoxigenic *E. coli* (EPEC), yak

Introduction

Pathogenic *E. coli* producing toxic agents are generally called enterotoxigenic *E. coli* (EPEC). EPEC can produce an exotoxin called enterotoxin, which mainly affects intestinal wall. There are two kinds of enterotoxins so classified on the basis of stability to heat: heat-labile enterotoxin (LT) and heat-stable enterotoxin (ST), including STI and STII. The present study involved investigations of diarrhoea epidemics in Naqu yak in Tibet, P.R. China. Pathogen identification revealed that pathogenic *E. coli* was the causal organism. Test of enterotoxigenicity was done in order to explore the pathogenic reasons.

Materials and methods

Strains

Three strains of enterotoxigenic *E. coli* (9901, 9903 and 9904) were isolated from Tibetan yak, which died during an epidemic.

Standard positive strain (C83902)

The standard positive strain was obtained from the Supervision Centre for Veterinary Medicine in China.

Experiment animals

Adult rabbits and newborn mice aged 1–3 days were obtained from the Institute for Experimental Animal of Chinese Academy of Medicine.

Bacteria culture

Improved Mundell medium was used to culture the strains. The culture was inoculated for 18 hours at 38°C. Shaking was required in the middle of the culture and the liquid culture was turbid.

Preparation of enterotoxin

The liquid culture was centrifuged for 15 minutes at a speed of 10,000 rpm and a film with diameter of 0.22 μm then filtered the supernatant. The filtrate was stored at 4°C for later use.

Detection methods of enterotoxin

Heat-labile enterotoxin (LT): Healthy rabbits weighing 2–3 kg, fasted for 36–48 hours, were used to do the ileum ligation test. Five segments were ligated, of which two segments were used as positive and negative controls each with infusion of 1 mL positive filtrate from the standard strain and 1 mL culture medium as negative, respectively, and the other four segments were infused with 1 mL of the filtrates from the strains of 9901, 9903 and 9904, respectively. Following 18–24 hours fasting, the rabbits were sacrificed and the ligated segments from the ileum were removed. The amount of liquid retained in each ligated segment was measured, and those, which had more than 1 mL liquid, were considered as positive. The length of each ligated segment was also recorded.

Heat-stable enterotoxin I (STI): Nine newborn mice aged 1–3 days were used to detect the STI in the filtrates of strains 9901, 9903 and 9904 by stomach lysis test. The animals were divided into five groups randomly. Each group had 2 mice except one, which had only 1 used as control. The filtrates were injected in the 1st, 2nd and 3rd groups, respectively. The positive filtrate of the standard strain and the culture medium were infused into the 4th and 5th groups as positive and negative controls, respectively. Each young mouse was injected with 0.1 mL of the liquids and kept alive for 2–4 hours at 25°C. The intestine and the remains of each mouse were weighed after the mouse was sacrificed. The ratio (G/C) of intestine [G] to the remains [C] was considered positive if it was more than 0.083.

Heat-stable enterotoxin II (STII): Adult mice were used to detect the STII in the filtrates of strains 9901, 9903 and 9904 by the ileum ligation (four segments of each animal) similar to that for the rabbits mentioned above. Of the collected filtrates 0.2 mL were infused into the two segments, and 0.2 mL positive filtrate of the standard strain and 0.2 mL culture medium were infused into the other two segments each as controls, respectively. Ratio (W/L) of the liquid retention in the ligated segments (mg) to the length of the ligated segments (cm) was considered as positives for the enterotoxigenic STII if it was more than 10.

Results and discussion

Detection of the IT

In the detection of the filtrate of strain 9901, the liquid retentions in the four ligated segments were 1.00 mL, 1.27 mL, 1.10 mL and 1.15 mL, respectively. The positive control was 1.15 mL and the negative one 0.70 mL. Corresponding results for strain 9903 were 1.51 mL, 2.75 mL, 2.36 mL and 1.25 mL, respectively, and the positive and negative controls were 2.48 mL and 0.95 mL, respectively. For strain 9904, the results were 1.00 mL, 1.29 mL, 1.43 mL and 1.25 mL, respectively, and corresponding positive and negative controls were 1.50 mL and 0.80 mL, respectively. Hyperemia of mucosa blood capillary was observed on the surface of experimental ileum of 9901 and 9903. They also had hemoid mucus. The positive control had the same features, but the negative one was different. Strain 9904 had the same appearance and the liquid in it was aqueous. The results indicate that the three strains of *E. coli* produce LT (heat-labile enterotoxin).

Detection of the STI

The G/C ratios for strain 9901 were 0.191 and 0.171. Corresponding values for strain 9903 were 0.218 and 0.210 while those for strain 9904 were 0.218 and 0.215. The ratios of G/C for the positive control were 0.238 and 0.153 while the negative one was 0.055. These show that the three strains of *E. coli* produced STI.

Detection of the STII

The ratios of W/L for strain 9901 were 40.5 and 50.2, while values for the positive and negative were 79.2 and 8.56, respectively. Mucosa of the experimental segments and the positive segment were hyperemic after the ileum was clipped. However, the ratios of W/L for strain 9903 were 137.3 and 148.5, and those for the positive and negative controls were 139.3 and 8.72, respectively. The ligated segments were full of hemoid mucus and the ileum mucosa was bleeding and had substantial hemoid seepages. The W/L ratios for strain 9904 were 151.1 and 146.1, and the corresponding values for the positive and negative controls were 172.2 and 6.7. Dark brown hemoid mucus was found in the positive and the experimental segments. The seepage in the negative segment was aqueous. The results suggest that the three strains produce STII, and that strain 9903 was hemoid, 9904 was aqueous and 9901 was intermediate.

In conclusion, all the tests in this study show that the three strains of 9901, 9903 and 9904 produced enterotoxins and that these are probably responsible for the diarrhoea in yak.

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Session VII: Products and marketing

Beef production of three yak breeds in Tibet

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Summary

Three animals from both sexes from the Pali, Sibü and Jiali yak (two males as an exception) were slaughtered to evaluate their beef production characteristics by various measurements. The results show that the dressing percentages, net beef percentages, ratios of net beef to carcass weight, eye muscle areas, and ratios of bone to net beef weight were 49.47%, 40.74%, 81.84%, 61.09 cm² and 1:4.56 for the Pali yak, 50.59%, 43.02%, 85.09%, 64.55 cm² and 1:4.21 for the Jiali yak and 46.67%, 37.4%, 79.62%, 45.41 cm² and 1:3.96 for the Sibü yak in Tibet, respectively. Further nutrients tests indicate that yak beef produced in Tibet is rich in protein, amino acids and minerals but less of fat. We, therefore, proposed yak beef production have a very promising market.

Keywords: Amino acids, beef, bone, minerals, dressing percentage, Tibet, yak

Introduction

Yak beef has higher protein and lower fat contents than normal beef. As a natural and ecologically clean food, the yak beef produced on the Tibetan Plateau has an increasing demand in recent years. Most importantly, yak beef is the main source of animal protein and energy to all the Tibetan nomads. This paper presents the measured characteristics of yak beef produced by three Tibetan yak breeds and explore the potential of yak beef production by considering the optimum slaughter time, reducing the input and enhancing the economy of Tibetan yak production system.

Materials and methods

Seventeen adult, healthy and middle body-conditioned animals grazing under natural pasture were purchased and transferred from Pali, Jiali and Sibü yak producing areas to Lhasa in 1997 and 1998. After several days acclimatisation and being fasted for 24 hours, the animals were slaughtered for various measurements to evaluate the beef productivity and related characteristics on site. Fresh samples were immediately collected, frozen and sent for further laboratory analyses in the Southwest Nationality College in Chengdu, Sichuan.

Results and discussion

Live weight

From both the body confirmation and live weight, it is found that the Pali yak is the largest, followed by Jiali yak and Sibü is the smallest (Table 1).

Table 1. Measurements of carcass of three yak breeds in Tibet.

Breeds	Sex	No.	Live weight (kg)	Carcass weight (kg)	Carcass length (cm)	Eye muscle area (cm ²)	Net beef (kg)	Dressing percentage (%)	Net beef (%)	Net beef/carcass (%)	Bone/beef
Jiali	G	2	314.45	157.89	134.00	82.25	140.89	50.38	44.97	89.24	1:4.16
	E	3	203.45	103.21	119.33	46.85	83.54	50.79	41.06	80.94	1:4.25
Pali	G	3	332.74	164.58	123.33	74.45	137.15	50.84	42.40	83.17	1:4.96
	E	3	221.59	106.58	111.33	47.72	85.75	48.10	39.08	80.50	1:4.16
Sibü	G	3	254.65	114.13	128.00	45.97	88.67	44.76	34.82	77.69	1:3.48
	E	3	205.94	101.29	120.67	44.84	82.62	49.18	39.98	81.55	1:4.43

Carcass measurements

Table 1 shows that Jiali male yak have the largest eye muscle area (82.3 cm²), followed by Pali (74.5 cm²) and Sibü yak (45.9 cm²), however, the value for female Jiali and Pali yak are almost the same and Sibü also is the smallest one. Most of the carcass characteristics of Tibetan yak are much lower than those of Jiulong yak, one of the top yak breeds in Sichuan (Zhong 1997), but the eye muscle area is just a little smaller than the Jiulong yak and larger than Tianzhu White yak in Gansu (50.3 cm²).

The Jiali yak further shows higher dressing percentage, net beef weight, net beef/carcass weight and eye muscle area than Pali and Sibü yak which represent that the beef productivity of Jiali yak is the best followed by the Pali and Sibü yak.

It was reported that that average carcass weights and dressing percentages for male and female Sibü yak were 206.87 kg and 53.15%, and 106.00 kg and 46.33%, respectively, and average carcass weights, dressing percentages, net beef rates, eye muscle areas and ratios of bone to beef were 208.5 kg, 55%, 46.89%, 50.63cm² and 1:5.63 for male Jiali yak and 128.34 kg, 49.54%, 42.76%, 43.28cm², and 1:6.70 for female Jiali yak, respectively (Dou 1990). Thus it is concluded that beef productivity of the Sibü yak has been tending to decrease. The dressing percentage and net beef rate of the Jiulong yak were 47–56% and 37.84–45.57%, respectively. The dressing percentage, net beef rate and ratio of bone to beef of the castrated adult Tianzhu White yak were 54.6, 41.4% and 1:4.07, and the dressing percentage and net beef rate of castrated adult Qinghai–Plateau and Maiwa yak were 53 and 42.5%, and 55.2 and 42.8%, respectively (Zhang 1989). The beef productivity of the Tibetan yak is still not very low considering the data from other breeds and is capable of being improved through feeding, management and selection of the breeding animals.

Nutrients and minerals in the Tibetan yak beef

Table 2 shows that the yak beef has higher crude protein but less fat, especially those found in the eye muscle. However, the crude protein in the rib muscle is higher than in the eye muscle, in particular for the females.

Table 2. *Nutrients of Tibetan yak beef (%)*.

Breeds	Sex	Muscles	Water	Crude protein	Crude fat	Ash
Pali	G	Eye muscle	74.24	22.56	2.06	1.033
		Rib muscle	54.93	17.82	25.29	0.843
	F	Eye muscle	75.22	22.18	2.41	1.07
		Rib muscle	43.61	15.04	40.5	0.675
Jiali	G	Eye muscle	75.25	21.38	2.33	1.05
		Rib muscle	68.35	21.23	9.42	1.00
	F	Eye muscle	74.37	22.34	2.22	1.07
		Rib muscle	69.01	19.11	11.01	0.87
Sibu	G	Muscles	73.39	22.60	2.98	1.03
		Eye muscle	68.18	20.45	10.43	0.94
	F	Rib muscle	73.42	22.86	2.72	1.00
		Eye muscle	58.60	17.86	22.67	0.87

Trace elements in the Tibetan yak beef is relatively higher than in the Jiulong yak, especially for Fe and Mg which are possibly resulted from the higher trace elements in the soil, forage and water but remains for future survey (Table 3).

Table 3. *Minerals in muscles of Tibetan yak.*

Breeds	Sex	Muscles	Zn (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Cu (mg/kg)	Mg (mg/kg)	Ca (mg/kg)	Co (mg/kg)
Pali	G	Eye muscle	83.470	81.598	30.892	30.892	304.813	324.235	0.071
		Rib muscle	39.130	83.176	19.525	13.863	258.057	297.560	0.128
	E	Eye muscle	92.138	91.293	29.621	25.581	314.034	308.986	0.236
		Rib muscle	64.275	111.984	34.036	31.663	215.513	290.014	0.203
Sibu	G	Eye muscle	94.827	188.693	46.599	25.842	187.147	-	0.1603
		Rib muscle	85.956	179.303	51.391	21.801	201.467	-	0.158
	E	Eye muscle	107.680	204.429	26.292	21.520	190.112	-	0.589
		Rib muscle	80.370	202.899	27.074	22.214	220.349	-	0.209

Amino acids in Tibetan yak beef

Beef of Tibetan yak is affluent in variety of amino acids but at a lower total content compared with the Jiulong yak (84.90 and 82.38% in rib and eye muscle, respectively) and Tianzhu White yak (90.18 and 91.16% in rib and eye muscle, respectively) probably due to

Table 4. Amino acids in muscles of Tibetan yak (%).

	Sibu						Pali						Jiali					
	G		E		G		E		G		E		G		E			
	Rib muscle	Eye muscle	Rib muscle	Eye muscle	Rib muscle	Eye muscle	Rib muscle	Eye muscle	Rib muscle	Eye muscle	Rib muscle	Eye muscle	Rib muscle	Eye muscle	Rib muscle	Eye muscle		
Aspartic acid	2.25	2.27	1.91	2.41	2.64	2.15	2.67	2.10	2.37	2.06	2.10	2.37	2.06	1.97	2.11			
Threonine	1.00	1.08	0.85	1.09	1.34	1.12	1.35	1.10	1.21	1.06	1.10	1.21	1.06	1.02	1.11			
Serine	0.81	0.84	0.69	0.83	1.14	0.89	1.18	0.87	0.99	0.83	0.87	0.99	0.83	0.83	0.88			
Glutamic acid	3.81	3.85	3.13	4.14	6.19	5.09	6.23	4.95	5.58	4.88	4.95	5.58	4.88	4.65	5.03			
Glycine	1.58	0.89	0.93	0.88	1.85	0.93	1.91	0.90	1.28	0.90	0.90	1.28	0.90	1.10	0.91			
Alanine	1.68	1.33	1.25	1.49	2.15	1.58	2.19	1.53	1.44	1.50	1.53	1.44	1.50	1.54	1.56			
Cystine	0.29	0.20	0.23	0.26	0.18	0.14	0.23	0.12	0.16	0.14	0.12	0.16	0.14	0.15	0.17			
Valine	1.09	1.03	0.93	1.15	1.44	1.17	1.50	1.14	1.29	1.11	1.14	1.29	1.11	1.10	1.15			
Methionine	0.58	0.66	0.52	0.71	0.67	0.56	0.64	0.54	0.57	0.56	0.54	0.57	0.56	0.46	0.56			
Isoleucine	1.02	1.03	0.86	1.15	1.40	1.20	1.39	1.16	1.32	1.18	1.16	1.32	1.18	1.10	1.22			
Leucine	2.01	2.04	1.74	2.19	2.61	2.16	2.28	2.10	2.39	2.10	2.10	2.39	2.10	1.98	1.12			
Tyrosine	0.74	0.81	0.65	0.89	0.92	0.81	0.96	0.79	0.87	0.79	0.79	0.87	0.79	0.69	0.80			
Phenylalanine	1.04	0.96	0.86	1.01	1.24	0.99	1.30	0.98	1.11	0.94	0.98	1.11	0.94	0.93	0.98			
Lysine	1.99	2.10	1.76	2.23	2.20	1.90	2.30	1.88	2.08	1.80	1.88	2.08	1.80	1.61	1.52			
Histidine	0.70	0.89	0.69	0.92	1.01	0.89	0.95	0.87	0.89	0.80	0.87	0.89	0.80	0.69	0.83			
Arginine	1.41	1.29	1.09	1.43	2.01	1.53	2.03	1.51	1.76	1.48	1.51	1.76	1.48	1.44	1.52			
Proline	1.06	0.64	0.72	0.66	1.42	0.83	1.44	0.73	1.02	0.75	0.73	1.02	0.75	0.85	0.76			
Total (%)	23.06	21.91	18.81	23.44	30.41	23.94	30.35	23.27	26.33	22.88	23.27	26.33	22.88	22.11	22.23			

its poorer feeding and management (Table 4). Among three breeds of Tibetan yak, the Pali yak has a higher total value of amino acids followed by the Sibü and Jiali yak.

Special remarks

Pali, Sibü and Jiali yak are three preferred yak breeds in Tibet, which have been supporting the Tibetan nomads' life providing the necessary productive and subsistence materials. Yak beef, rich in protein, amino acids and trace minerals and less of fat, is the main product of yak production, which plays a key role in providing animal protein and energy to the Tibetans living on the cold highlands. It is also natural and unpolluted green meat favoured by the increasing markets. Tibet has a large number of yak and related natural resources to support a sustainable yak industry. However, owing to the constraints from both the marginal eco-geographical location and infrastructures, the potential of yak production has not been well developed. The authors recommend that an effective use of the natural forage resource should be considered for the sustainable yak production, the key backbone industry to the local Tibetan socio-economy.

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Diversification in processing and marketing of yak milk based products

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Summary

Nepal was the first country to produce cheese from yak/Chauri milk in the high alpine region of the country. This product is popularly known as yak cheese. Nepal produced around 350 t of cheese during 1998/99, out of which around 150 t was from yak and Chauri milk. This activity is focused in the districts of Mount Everest trekking route and the Rasuwa district, adjoining to the capital city. Many more districts, stretching over the northern alpine region, raise yak as the main means of subsistence. Yak milk is traditionally processed into fermented milk, and then churned out to produce local yak butter and buttermilk. Buttermilk is further processed into sher, a cottage cheese type product. If fermented, produces sewsew, and if pressed and dried or dried without pressing it becomes Chhurpi, a dried hard casein product. Chhurpi is widely consumed by Himalayan people as a source of nutrients, and is chewed to maintain salivation during mountain climbing. Traditional and indigenous technologies are in place to produce milk products that have long shelf life in the yak rearing countries of China, Bhutan, India, Mongolia, Pakistan, Nepal and so on. There is a need to upgrade the existing indigenous technology to produce safe and hygienic yak milk products at commercial scale. Human resource development and training facilities, yak milk processing industry association and marketing and promotion are the major issues to be addressed to promote the yak trade. The International Yak Congress should come with a consensus to establish an International Yak Research Centre that could carry out the research, education and training, development of appropriate technology, standardisation of products and processes, and other areas identified by the yak-producing countries. Diversification is very essential to generate sustainable income, and it is only possible when proper practical training and technology is transferred to the beneficiaries.

Keywords: Cheese, Chhurpi, indigenous technology, promotion, yak cheese

Introduction

Diversification should entail producing varieties of milk products from yak/Chauri milk, and that also adds value to the species. This is basically intended to fetch more return for the producers per unit of milk produced. Yak and Chauri have been reared and herded on either side of Himalayan range, from Tibet in the north to the southern slopes covering

parts of India, Nepal, and Bhutan (Joshi et al. 1994). Yak butter is considered as an excellent source of energy, and local people say this is very good for the body and strength. A long tradition of milk production, processing and consumption exists in the high alpine Indo-China region. The essence of processing was concentration and increasing the storage life of milk by reducing the water content through concentration of protein or fat, or fat and protein together. The water content is traditionally removed through evaporation or coagulation and draining or other processes like separation of valuable constituents of milk that can be stored for a considerable length of time, and which fetch better prices. This resulted in the production of butter, ghee, Chhurpi and so on. Butter and ghee are concentrated milk, with much longer shelf life than milk. Similarly, Chhurpi is a milk protein concentrate with very low moisture content. In the western world, milk protein was not concentrated into Chhurpi, but into cheese. There was added advantage in cheese making: Protein and most of milk fat could be concentrated, stored and transported. The Swiss developed appropriate technology to produce cheese in the Alps Mountain. Later on, this technology was transferred to Nepal through FAO technical assistance in 1952. Thus, first yak cheese plant was established in Langtang valley. This dates back to first historic yak cheese production in Nepal, and Nepal became the first country in Asia to start a cheese industry. It was the only country in the world producing yak cheese before 1980s. Hard Swiss Gruyere type cheese was produced. This cheese is popularly known and marketed by the name of Yak Cheese today (Thapa 1996).

Nepal produced around 350 t of cheeses during 1998/99, out of which about 150 tonnes was from yak and Chauri milk (Table 1).

Table 1. *Yak cheese production in Nepal (1998/99).*

District	Yield (tonnes)
Ramechhap	50
Dolakha	18
Solokhumbu	7.5
Rasuwa	12
Total production by private sector processors	87.5
Yak cheese production by the six Dairy Development Corporation (DDC) plants	60
Approximate total yak cheese production	147.5

Chhurpi is the dried hard casein product traditionally produced from yak or chauri (crossbred yak × chauri cattle) milk in the Himalayan region of Nepal, Sikkim and Bhutan. Similarly, Serkam is a local dairy product, prepared by boiling and draining liquid portion of buttermilk and in some cases whey. The remaining solid is Serkam. It is used fresh or can be used after certain period, ranging between days to months. However, long storage causes natural fermentation, giving off typical flavour but is liked very much by Jirel and Sherpas. In China, excellent examples of diversification exist, including the processing of yak milk into powder.

Chhurpi making technology

The commercial Chhurpi makers prepare the product in a batch using 169 litres of skimmed milk (SM) under local condition. The workflow of standardised process adopted by local *Chhurpi* maker in Nepal is described below.

Two hundred litres of milk (6.5% fat and 9% solid-not-fat) is separated to 31 litres of 40% fat cream and 169 litres, skimmed milk (SM). SM is heated to 60–65°C in aluminium kettle under direct fire. Then 40 litres of Dahi (fermented milk) made by using SM is added, with constant stirring. The curdled mass is cooked by boiling for 30 minutes or until long threads or chains are formed. Then 50–60 litres of whey is drawn out. The kettle is taken out of fire after colour changes to creamy yellowish. The cooked curd is strained and pressed for 24 hours using stone weights. The pressed curd is cut into small cubes and air-dried on a bamboo mat in a well-ventilated room. The product is hard enough after 12–15 days of air-drying. Alternatively, the product is smoke-dried after 10 days of air-drying. Chhurpi yield is 4.5% with 8–10% moisture, 8–9% fat and 80% protein on dry matter basis. The technology has been very useful to the remote and mountainous milk producers who do not have access to raw milk market. The producers are able to convert perishable milk into long life products like Chhurpi, butter and ghee. The technology has been quite useful to generate cash income and local employment at the rural level.

Further work is needed to improve the quality and the profitability of final product and to improve the technology appropriate to the rural producers.



Figure 1. *Chhurpi* sale in Kathmandu market.

Yak cheese manufacturing technology

Thapa and Sherpa (1994) reported the yak cheese manufacturing technology adopted by Dairy Development Corporation, Nepal. Thapa (1997) described further improved yak cheese making procedures used by the Nepalese yak cheese manufacturers. The recently improved and standardised method is presented below.

Raw milk (7–8% fat and 9.5–10% solids not-fat) is used. Standardise the milk to 3.5% fat by cream separation; cream is churned into butter. Follow in-can pasteurisation of cheese milk at 65°C/5 minutes by immersing in a boiling water bath, and cooling in water-trough to 33–35°C. Transfer the cheese milk to 200–300 litres copper kettle and put on a traditional fireplace. Add 0.5% culture (*Str. thermophilus* and *Lactobacillus helveticus* 1:1). After 5 minutes add rennet solution (2.5 g dissolved in 500 mL boiled and cooled water for 100 litres milk) and stir for one minute before allowing to set (33°C) by covering the kettle. Turn the top curd using scoop after 30 min and allowed to set for 5 more minutes. The curd is cut, and after 5 min stirring started very slowly. Continue stirring for 25 min (32°C) before cooking is started. This is called pre-stirring. The curd is cooked to 50–53°C in 30 minutes using firewood. The temperature is gradually raised in the following manner: 32–35°C/first 10 min; 35–45°C/second 10 min; 45–50°C/last 10 min. After the temperature reaches 50°C, continue stirring for 25–30 minutes until the curd is ready for moulding and pressing. Pressing: Cheese is pressed in two stages; Pre-pressing; the blocks are turned after 5 min, 15 min, 45 min and after 1.5 hours. Wet cloth is replaced by dry cloth after 1.5 hours. Final pressing; fifth turn is given after 3.5 hour and dry cloth is used. After six hours, cheese is pressed without cloth till next morning. Total pressing time ranges between 16–17 hours. Cheese blocks are saturated (24%) generally for 48 hours, but the saturating time is proportional to the weight of the blocks. 5–6 kg blocks are saturated for 36 hours whereas 14–15 kg blocks are saturated for 72 hours. The cheese blocks are stored for ripening at 10–12°C and 85–90% humidity for first two weeks; and then at temperatures of 20–22°C and 75–80% humidity for 2–8 weeks. After this period cheese is transferred to maturing store at temperatures of 8–10°C till marketed. In high alpine region (2500–3400 metres above sea level), it is stored under ambient temperature condition. For first week, cheese is washed and turned every day, then twice a week for 3 weeks consecutively. The cheese develops good flavour after 5 months of ripening. Green cheese yield is 11% and 6–8% of original weight is lost after 5 months curing.

Diversification potential

Excellent potential of diversifying processing and marketing of yak milk-based products exists in the whole of the yak-rearing zone of Indo-China. Yak cheese is an established name for the yak milk-based product. Nepal produces less than 200 tonnes, and Yak cheese is almost an established brand name. The benefit of this established name could be taken advantage of by the other yak rearing countries. Yak cheese has a well-established market, particularly in the tourist-dominated areas of Nepal, and is fetching relatively high prices.

Yak cheese demand is not even fulfilled in Nepal, and there is demand from other countries too. Yak cheese has, therefore, a big potential. Yak cheese has market expansion potential in neighbouring countries too. However, low level of production and poor marketing channels has constrained the export of the product. Countries with sizeable yak milk production can develop the yak cheese production to a commercial scale, targeting export market in the west.

Interventions needed

Basically, to promote diversification, there is a need, firstly, to upgrade and standardise the indigenous technology to commercialise the indigenous system. Secondly, already established technology like Yak Cheese Technology could be exploited to a higher level of production, targeting export market. Nepal could assist the other countries in this regard. Marketing and promotional campaign are very essential to expand the trade. Proper packaging, using registered brand name, can ensure higher profit for the producers and marketers. The development of a regional brand for yak cheese is an option.

The International Yak Congress is an appropriate forum, and should come out with a consensus to establish an International Yak Research Centre, that could carry out the research, education and training, appropriate technology development, products and process standardisation, and other identified priority areas. Diversification is very essential to generate sustainable income, and it is only possible when proper practical training and technology is transferred to the beneficiaries. The International Yak Congress should also consider establishing a Technical Exchange Programme to share the experiences existing within the region, through multi-lateral donor assistance.

Closing remarks

The International Yak Congress should focus on the following areas to promote diversification for the increased income to the yak and Chauri farmers:

1. Without skilled and trained manpower, the industry cannot produce and market quality yak cheese and other dairy products. Thus, establishment of dairy training facility and human resource development programme is crucial. This would be possible through the establishment of an Asia Regional Yak Cheese Training Centre at an appropriate location in the yak-rearing region.
2. The brand name for the yak cheese should be registered and used; a common regional brand name could be considered.
3. The International Yak Congress should come up with a recommendation to establish the International Yak Research Centre, that may help to address the problems related with the research, education and training, appropriate technology development, products and process standardisation, and other areas identified by the yak-rearing countries. Diversification is essential to generate sustainable income, and it is only possible when proper practical training and technology is transferred to the community.

4. Technical exchange programme should be established that would help to share experiences within the region, and the programme could be funded through members and multi-lateral donor assistance. International Centre for Integrated Mountain Development (ICIMOD), and other organisations working in the area of mountain development, could assist the cause of neglected yak-rearing communities of Indo-China region.

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Development of yak veal and related technology as a means of increasing overall yak productivity

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Introduction

Qinghai Datong Yak Farm is a state-owned yak farm, which was established in 1952. There are 51 ha usable pasture and 20 thousand yak and other livestock. Yak production is the main source of income for the farm. However, the growth and development of yak have been slow due to traditional extensive management and poor, degenerated, vegetation caused by overgrazing, which has been going on for a long time. To change this situation, and after consulting the scientists of Lanzhou Research Institute of Animal Science of Chinese Academy of Agricultural Sciences and Qinghai Academy of Animal and Veterinary Sciences, the farm began to carry out the seasonal animal husbandry with slaughtering male yak calves at six months of age for veal production.

Over 43 thousand male calves have been slaughtered during the last 13 years (up to 1997), with an average of 3980 male calves each year. The slaughter rate was up 57% during this period. The output value of the slaughtered calves accounted for 20% of the total income of the farm. The results suggest that this measure, not only enhanced the development of yak husbandry, but also formed a new opportunity for the economy in the pastoral area. It will play an important role in the development of animal husbandry in the future.

Processing value of veal and its by-products

The nutritive composition of the yak veal in the Datong Yak Farm was analysed (Table 1). The results showed that the yak veal is nutritive meat. It is fresher and tender, has lower fat, higher protein and is richer in minerals compared with the yak beef.

Table 1. Comparison of nutrients between the yak veal and beef (%).

Item	Dry matter	Crud protein	Crud fat	Crude mineral	Calcium	Phosphorus	Calorific value
Veal	30.5 ± 0.3	24.1 ± 0.1	5.1 ± 0.1	1.4 ± 0.02	0.04 ± 0.01	0.11 ± 0.01	5987.0
Beef	35.4 ± 0.5	27.6 ± 0.1	6.2 ± 0.3	1.6 ± 0.02	0.06 ± 0.01	0.12 ± 0.01	7157.0

The yak calves live in the cold and high alpine pasture at an elevation of over 3000 metres above sea level where there is no pollution and contaminants from pesticides, fertilisers and other chemical pollutants. Yak veal is ideal for roasting and stew because it tastes fresh and is tender. It is a product, which can do well in both local and international markets.

The advantages of veal production

Increasing the reproductive rate

Normally, the yak cow only gives birth from March to May every two years, mostly due to the poor body condition of the nursing cow since the yak calf is only weaned the following summer. According to a survey, proportion of cows calving every year in yak herds was less than 20% under traditional system before 1984. It has been shown that, if the calf is weaned in early autumn, the cow may get oestrus 5 to 10 days after the lactation ends (after the calf is slaughtered). This substantially increases the reproductive rate of the herds. In the study farm, the conception rate reached 62% and the proportion of cows calving every year increased by 38% after the veal production had been implemented starting in 1985.

Improving the herd structure

Using a strategy of slaughtering the male calves at 6 months of age and poorly-developed female calves, and culling cows with poor reproductive performance and reducing the number of animals in the 9 to 24 month age range, increased the percentage of reproductive females and, in turn, improved the reproduction at herd level. For example, the reproductive cows took only 49% in 1983, but it was up to 54.7% in 1995 in the Datong Yak Farm.

Enhancing the marketing rate

The study has shown that the body weight gain of calves nursed by un milked cows was highest by the age of 8 months. So, veal production taking full advantage of all the cow's milk, which is translated into high calf growth rates, substantially enhances the marketing rate and economic income. Results of analysis of calf live weights in the farm showed that the percentage of six-month-old yak calves with carcasses weighing 35–45 kg, 40–45 kg and over 45 kg were 40–43%, 30–35% and 22%, respectively.

Reducing the economic loss from natural disasters and body weight loss over the winter and spring seasons

The yak calves get all of their nutrition and energy needs for growth and development from their mothers. But in harsh winter and spring seasons on the Qinghai-Tibetan Plateau, the yak cow can only support itself with the nutrition from natural pasture and provide very little for her calf. Under these circumstances, the starving calf resorts to nibbling the forage by itself from an early age, resulting in reduced physique, extreme weakness and lowered resistance to all kinds of diseases and natural disasters. This results into increased calf mortality. According to statistics from Qinghai Datong Yak Farm in 1984, calf mortality was over 13%, representing up to 74% of the overall mortality of yak in the herd. Therefore, slaughtering the yak calves can reduce this kind of loss under the harsh conditions in spring and winter.

Controlling overgrazing and decreasing the pressure on winter and spring pasture

Generally, calving season of the yak cow begins in March. If the calves born in the year are not slaughtered, the requirement for forage increases, especially during winter and the following spring when the grass withers. The veal production is an alternative to solve this problem. Moreover, this measure can also reduce labour costs and the investments on basic infrastructure by about 100 RMB Yuan (US\$ 1 = 8.2 Yuan during this study) per calf slaughtered.

Qinghai Datong Yak Farm has made an important contribution in the development of veal and its related by-products. The project, titled 'Technique of increasing output from developing the yak veal' has been confirmed as one of the extended projects of 'harvest scheme of national agriculture, animal husbandry and fishery' by the Ministry of Agriculture and is receiving great attention from the Animal Husbandry Department of Qinghai Province and other related departments.

Composition, quality and consumption of yak milk in Mongolia

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Summary

The milk yield of yak and its hybrid, the 'khainag', is 300 and 470 kg, respectively. However, yak milk has higher density, and fat, protein and sugar contents. The larger diameter of fat globule (5 to 6 μm) makes the separation of butter easier in yak milk than in milk of other animals. Therefore, the yak milk is suitable for making milk cream. Because yak milk is rich in carotene, the butter is of yellowish colour and very delicious. Associated with the high protein content is the high acidity of yak milk. Among the fatty acids of yak milk, the saturated and unsaturated types constitute 22% and 55.2% of the total, respectively. The concentrations of low molecular weight volatile acids and vitamin F in milk of yak and its hybrid are higher than that in cattle. Regarding the differences between the lipid amounts in the yak milk during winter and summer seasons, the technology of butter production suited for the seasons has been developed. Mongolians produce a large range of products from the yak milk. They may be classified into the products of butter, fermented and protein products. Butter products include milk membrane (*orum*), and yellow and white butter. The fermented products are yoghurt and koumiss (*airag*); wet and dried curds (*aaruul*) are the protein products.

Keywords: Amino acids, fat, fat globule, fatty acid, fermentation, hybrid, mineral, protein, sugar, yak

Introduction

Because of the popularity of yak milk and its products, the milk products made in the areas where the yak is bred are well known throughout Mongolia. The butter pre-processing factories utilise the raw materials from these areas. Baterdene (1961, 1988) has studied the yield and composition of yak milk. These studies reported that the lactation length of yak cows calving in February or March was 283 days, while it was 231 days for yak calving in April. In other words, the length of lactation (and hence milk yield/lactation) depends on the time of calving. The dry matter, fat, protein, sugar and minerals (ash) account for 19.3, 7.89, 5.31, 5.21 and 0.95%, respectively, of yak milk.

Indra (1983, 1997) has studied the technology for traditional processing of milk products in Mongolia in relation to milk quality and has attempted to explain the peculiarities of the technology developed by nomadic livestock farming communities.

Lkhagvajav (1978) investigated the lipid components of yak and Mongolian cattle milk in different seasons.

The present study was undertaken to investigate the features of the yak milk composition and technology of milk processing as bases for any future development of industrial-scale processing of yak milk.

Materials and methods

Ten cows, similar in their calving periods, milk yields and live weights from yak, Khainag (hybrid) and Mongolian cattle herds were used for the study. Milk samples were taken from each experimental animal during each month of lactation.

Results and discussion

The milk composition in yak, khainag and Mongolian cattle is shown in Table 1.

Table 1. Composition of the milk of Mongolian cattle, yak and Khainag.

Parameters (%)	Mongolian cattle	Yak	Khainag
Density	29.61 ± 0.060	33.08 ± 0.199	32.00 ± 0.028
Souring	20.60 ± 0.096	21.84 ± 0.052	22.30 ± 0.300
Fat	4.28 ± 0.098	0.79 ± 0.124	5.58 ± 0.143
Protein	3.42 ± 0.030	5.03 ± 0.110	4.29 ± 0.235
Sugar	4.75 ± 0.020	5.10 ± 0.021	4.84 ± 0.074
Ash	0.80 ± 0.05	0.86 ± 0.009	0.93 ± 0.049
Dry matter	13.25 ± 0.104	17.78 ± 0.229	15.64 ± 0.325

The fat content of yak milk was higher than that of native cattle in the highland areas by 58% while the protein amount was higher by 47% (Table 2). The sugar and mineral contents were also higher. As a result, the total amount of dry matter in yak milk was also higher than that of the native cattle. The composition of the Khainag's milk was about the average of Mongolian cattle and yak. The coagulation capacity of the yak and Khainag milk was higher than that of Mongolian cattle by 2%.

A feature of the yak milk is its higher coagulation capacity resulting from high concentration of calcium. This is connected with the higher amount of minerals, particularly salts of phosphoric acid and proteins (Table 3). The areas in which the yak are raised for milk production are famous for yak milk products throughout Mongolia. These areas produce largest amount and highest quality of butter.

Because the yak and Khainag milk is rich in protein, which has higher clotting and coagulating capacity, forming dense and homogenous coagulum, the milk is suitable for making protein products such as cheese, wet and dried curds. A major protein in the yak milk is casein, which accounts for 5.03% of total protein and 1.5% higher than that in cattle. It is capable of forming a dense coagulum in the presence of both lactic acid and

stomach enzymes. Yak milk (132 mg/100 mL) has higher calcium content than cattle milk (124 mg/100 mL). Therefore, yak milk is well suited for cheese, yoghurt and curds, which are protein products.

Table 2. *The amino acid contents of the milk of cattle and yak.*

Amino acids	Mongolian cattle	Yak
Cystine + cysteine	1.17	0.90
Lysine + histidine	11.65	11.53
Arginine	3.91	3.24
Aspartic acid	6.91	6.24
Serine	4.02	4.24
Glycerine	2.75	2.54
Clutamic acid	17.73	17.18
Threonine	4.09	4.09
Tyrosine	3.41	3.53
Alanine	2.73	3.20
Proline	2.75	2.54
Methionine	2.85	2.54
Valine	5.70	5.66
Phenylalanine	4.19	3.99
Isoleucine-leucine	18.67	18.08
Total	93.94	19.11

Table 3. *Mineral composition of milk of yak, Khainag and Mongolian cattle.*

Breeds	Ash (%)	Calcium (mg/100 mL)	Phosphorus (mg/100 mL)
Yak	0.89	130.6	106.22
Khainag	0.93	134.0	134.82
Mongolian cattle	0.88	124.91	97.82

The amino acid content of yak milk was not different from that of cattle (see Table 2 above). Of course, essential amino acids are the same as those in the milk of other animal species, including glutamic acid, leucine, isoleucine, lysine and histidine.

Because of large diameter of fat globules in the yak milk [5 to 6 µm (1 to 10)], the fat globule is built up for 44 minutes in average (60 minutes in cattle). Due to the large size of fat globules, the loss of butter during separation is lower, and 97% of butter is extracted.

The saturated and unsaturated fatty acids constitute 65.2% and 34.8%, respectively, of the total fatty acids in the yak milk, and they include 22 kinds of fatty acids. The total percentage of low molecular weight fatty, capryne, caprice and caprylic acids, which are responsible for the smell and taste of fat, is 7.2%. Among the saturated acids, palmitin (29.2%) and stearin (14.9%) are dominant. Olein occurs mostly among the unsaturated fatty acids and there are 5.5 to 6.0% multiple bond unsaturated acids or vitamin F. This is found in very little amounts in the milk of cattle (Table 4).

The presence of linoleic, linolenic, arachidonic and enozen acids in the yak milk indicates the biological activity of yak milk. There are some seasonal differences in the butter of yak milk. In winter, the amount of volatile acids is higher, while the unsaturated acids are lower compared to summer. As a consequence, the expansion coefficient, melting temperatures and hardening of butter are different during winter compared to summer. Because of higher fat content in the yak milk, the concentrations of fat-soluble vitamins are also higher.

Table 4. Fatty acid contents of butter from milk of cattle, yak and Khainag.

Fractions of fatty acids	Milk butter		
	Mongolian cattle	Yak	Khainag
Saturated fatty acid (C12–C20)	60.4	58.0	57.0
Low molecular weight volatile acids (C4–C10)	6.6	7.2	9.3
Unsaturated acids	33	34.8	33.4
Double bond linoleic, linolenic and arachidonic acids	2.1	5.5	5.4

To make Swiss- or Holland-type cheese from yak milk, detailed studies of coagulation capacity, curd composition and types is essential. Such studies are necessary to facilitate the development of new technology of cheese production and to determine what kind of cheeses can be made using yak milk. Mongolians produce many kinds of products from yak milk. They are classified into butter protein and fermented products.

Mongolian technology of milk products is quite developed in relation to the specific ecological and central Asian dry climate with high fluctuations between day and night temperatures and conditions of nomadic livestock farming. Manufacturing of Mongolian milk products does not require any sophisticated equipment.

Butter products include milk membrane, white and yellow butter

A layer of protein and lecithin on the milk surface—‘*orom*’—which is formed after 24 hours of keeping in static position followed by boiling of the milk and frequent mixing. Under this layer, fat globules are deposited forming another thick layer. Finally, these layers or milk membrane are picked up, having a bend through the diameter line. The yak milk ‘*orom*’ has 20 to 25 mm thickness and is used for daily consumption and for special meals, e.g. for guests. Daily portions of ‘*orom*’ are stored in a specially prepared container, and go through lactic and propionic acid fermentation; they are melted to obtain yellow butter. The remainder is called white butter, which consists of protein and fat. This kind of butter is used for food during winter in mixtures with sugar and other products.

Fermented products in yoghurt and koumiss

The coccus and rod shaped lactic acid bacteria and yeasts in their symbiotic lifestyle are key in the fermentation process. Depending on the temperature and microbe types, two types of products differing in taste and quality can be produced:

1. To make yoghurt, the milk is boiled and milk membrane is picked up. Then the milk with 1.5% fat is heated to 45°C for preparation of initial source material and sealed and left to ferment.
2. Using the similar source material, the koumiss or airag is made by fermenting at 20°C with mixing for airflow. This process causes induction of yeast activity, souring by lactic acid and formation of the acid products containing alcohol. The end product is the koumiss or 'airag'.

This product can either be consumed directly or it can be used for processing wet and dried curds. Because they can be stored for extended periods and easily transported, these products are a kind of protein concentrate and dried food, consumable all year round. To make curd, the yoghurt or koumiss is heated lightly and filtered to collect the curd then wet curd is cut in various shapes and dried. Curdling fresh milk with lactic acid produced another kind of dried curd called 'Eezgii', and the mass is boiled until the milk liquid is evaporated. Then the mass is dried in open air.

To make cheese, the milk of yak is heated up to 84°C and curdled by lactic acid. No microbiological process takes place during production of Mongolian cheese, which is a drained and pressed coagulum. It weighs about 3 to 4 kg and is square with obtuse angles. Cheese is a favourite food of Mongolians and is used in fresh form. To store the cheese, it is cut into thin pieces.

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Protocol for the manufacture of high quality, nutritive bone marrow powder product from Tianzhu White yak

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Summary

A nutritional and healthy food is manufactured from a combination of bone marrow and bone powder of Tianzhu White yak, wheat and soybean flour, and additives. The food contains 11.5% of protein, 3400 Kcal/kg of energy, 23 g/kg of calcium and 639.9 mg/kg of iron. High pressure, decompression and condensation protocols are used to extract the bone marrow. Extrusion and expansion approaches increase dissolubility of α -starch from wheat.

Keywords: Bone marrow powder, manufacture protocol, quality, Tianzhu White yak

Introduction

To better use the resource of Tianzhu White yak, this study develops a protocol to produce a nutritional and healthy food product consisting of bone marrow powder from the yak bone, wheat, soybean and additives. This paper reports a detailed protocol for the manufacture of the product.

Materials and methods

Fresh bone collected from the Tianzhu White yak feeding on the natural pasture at an altitude of 3400 metres above sea level (masl), wheat, soybean and vegetable oil (purchased from selected commercial markets), and additives (*gingeli*, peanut, salt, monosodium glutamate and others) are used as raw materials. Compound aluminum foil bag is used as packaging material for the finished product.

Multiple bulking machine (SDP-90), *muller* (45A-80), mixing machine (DF), granule machine (YK-160), puffed food firing machine (YHW), automatic granule package machine (DXDK150II), autoclave (GT7C5), decompression and condensation pan (MZN-500), and store pot (GRJC-G600) are used in the processing protocol. Based on the daily nutritional requirement of an adult person as recommended by the Chinese Association of Nutrition, intake and interactions among the nutrients, the formula is developed and screened by taking into consideration necessary solubility properties. It consists of 14% condensed bone

marrow solution, 63.5% bulked wheat flour, 10% bone powder, 10.5% additives and 2% vegetable oil.

Condensed bone marrow solution is made from the bone by washing, breaking up, extraction under high temperature and pressure, and condensation through decompression. The fresh bones, especially the vertebrae and other tubule bones of the Tianzhu White Yak are selected and dipped in the water for 2–4 h to remove the blood residue. To be easily broken up, the washed bones are frozen at -20°C for 3–4 h and then autoclaved with a ratio of the broken bone to water of 1:0.5 under 0.25–0.3 Mpa and 121°C for 4 h to extract the bone marrow. The solution is filtered and transferred to the decompression and condensation pan for condensation under -0.06 Mpa and 60 – 70°C for 2–3 h to make 94% of the water vaporised. The rest is the condensed bone marrow solution, which accounts for about 33% of the fresh bone weight.

The bone residue after bone marrow extraction is used to make bone powder with a granularity smaller than $70\ \mu\text{m}$ through milling, drying, grinding and sifting.

A mixture of wheat and soybean flour is prepared by extrusion, expansion, grinding and sifting. First, the wheat and soybean is desquamated after adding water to a humidity of 10–14% and transferred to the puffed food-firing machine which is maintained at $160 \pm 10^{\circ}\text{C}$. The mixture is melted under 3–8 Mpa and 200°C , expanded by sudden release to the normal pressure, and solidified under 80°C . Then it is grounded by the *muller* and screened into powder smaller than $60\ \mu\text{m}$.

The finished product is prepared according to the formula above after mixing, granulating into $1.5\ \text{mm}^3$ size, drying at 80 – 85°C for 2–3 h, weighing and packing into bags weighing 30 g each.

The protein, fat, dry matter, energy, minerals, expansion (area of cross section of the bulked granule to area of machine matrix), viscosity (valued in Mpas after dissolving the product in water at a ration of 1:8), dissolubility (percentage of undissolved dry residue in the 10 g product dissolved in water at a ration of 1:9 at 90°C for 10 min), and related quality (hygiene) indexes are measured.

Results and discussion

Properties of the finished product

The finished product is yellow-brown in colour and has a very nice flavour of baked wheat and faint scent. The granules are very uniform in size and dissolubility is very high with a viscosity of 61.5.

Building up condition and dissolubility

Both the building up condition and dissolubility of the finished product are improved by the extrusion, expansion and granule-making procedures. After being puffed, the starch of

wheat is fully converted into α -form with plenty of $-OH$ groups that are easy to combine with more water to improve the viscosity of dissolved product.

Nutritional and quality measurements

The dry matter, protein, fat, energy, calcium, iron and zinc contents are 86.7%, 11.52%, 20.26%, 3,400 Kcal/kg, 23 g/kg, 639.9 mg/kg, and 10.82 mg/kg, respectively. The protein, energy, calcium and iron contents are higher than those in common plant-based foods and milk. The higher energy is particularly helpful for nomads living at high altitude, under cold temperatures and high humidity. All the quality (hygiene) indexes match national and international standards.

Relationship of expansion of mixture of wheat and soybean flour with the warming up temperature of the matrix and the feeding in speed

The optimum warming up temperature of the matrix and feeding in speed of the mixture are 160°C and 0.9–1.0 kg/min (Figure 1).

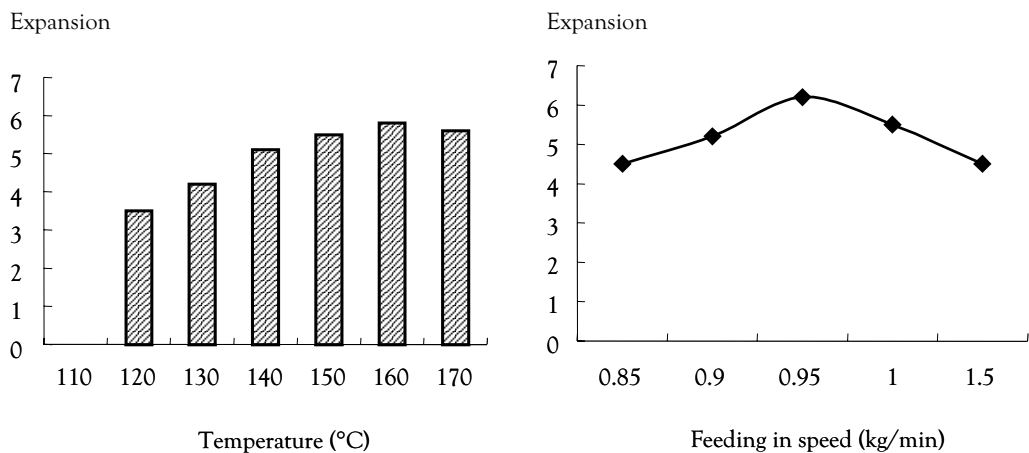


Figure 1. Effects of the warming up temperature of the matrix and feeding in speed on expansion of the mixture of wheat and soybean flour.

Optimum ratio of soybean to wheat in the mixture

It is well known that protein content in wheat is relatively low, and the amount of the essential amino acids is limited. However, the soybean is rich in protein but has a high fat content, and this presents a problem during the bulking treatment. An attempt has been

made to try to optimise the ratio of wheat to soybean in the mixture. The ratio of 9:1 has been found to be the optimum for bulking effectiveness (Table 1).

Table 1. Effect of ratio of soybean to wheat on the expansion of the mixture.

Soybean:wheat	10:90	15:85	20:80	25:75
Effectiveness	Good	Good	Better	Oil
Expansion	5.8	5.1	4.0	2

The new product developed from the Tianzhu White yak is a natural, healthy food. It is full-bodied and is in accord with the standards of traditional food habit of the local Tibetan nomads. Popularisation of this product for its expanded use provides a means of increasing the use of the natural yak resource and for increasing the income of the yak herders in the region.

To summarise the manufacture protocol, the optimum parameters for the warming up temperature of the matrix is 160°C, the feeding in speed of 0.9–1 kg/mi and ratio of wheat to soybean 9:1. The size of the bulked granule is 1.5 mm³ and the condition to extract the bone marrow is 0.25–0.3 Mpa and 121°C for decompression, and –0.06 Mpa and at 60–70°C for condensation, by which a 33% concentrated bone marrow solution is harvested from the total fresh yak bones.

Development of yak products and their processing and marketing

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Summary

As a unique animal inhabiting the very high mountain pastures, yak has no competition from any domestic livestock, but there is some competition from the wild animals. Breeding in ecologically clean environment, rich in energetically saturated forage, yak produce extremely valuable food materials (meat, milk, fat) and non-food items (wool, leather, faeces, horn, blood, bones etc.). Only a few mountainous countries have yak breeds. These countries have a unique opportunity to improve their economic and social life by effectively exploiting the yak and its products. Kyrgyzstan is among these countries and Kyrgyz people living in high mountainous regions have good tradition of breeding yak and processing yak raw materials.

Entering a new stage of independence, Kyrgyzstan needs new initiatives and ideas for economic and social development. In the National Program on Preparation and Conducting the International Year of Mountains, yak development is identified as one of the main priorities of the economic development of the mountain regions of Kyrgyzstan. A working group of scientists and practical workers has been formed and adopted by the Prime Minister's decree, with the mandate to work out the 'Strategy of the Complex Development of Yak Breeding in Kyrgyzstan' and a 'Project devoted to the implementation of the strategy'.

The main objective of the Project is to use the unique yak raw materials and available modern technologies of processing to produce high quality products meeting international standards for domestic and international markets so as to contribute to the development of economic and social life of the mountainous regions and the country as a whole.

There is no doubt that, from the ecologically clean environment, if yak raw materials are processed into unique and high quality products using modern advanced technologies. If, in addition, marketing is well organised, there could be a great opportunity for accessing expanded internal and external markets. In turn, expanded market of the unique yak products can provide an excellent chance to develop yak production in the region and to enhance the economic and social life of people living there.

The last is the main target and the final result of the whole process of yak breeding and processing yak raw materials and marketing products.

In the process of working on the strategy for yak development, we in Kyrgyzstan have identified several challenges. These challenges must also be facing other yak-rearing

countries. Therefore, their solution is of interest not only for Kyrgyzstan but also for all so-called yak countries and others who are interested in yak products.

1. So far there is no national or international standard on yak products—on food products as well as non-food ones. This makes it very difficult to develop marketing. To overcome this problem, there should be certain research implemented to develop national and international standards on yak products.
2. There is very little information concerning marketing of yak products. For instance, in Kyrgyzstan there is only some market information on fresh yak meat. This problem is closely related with the first one. If there are standards the yak marketing will have very important base for promoting yak products, not only in domestic market, but also international as well. Creation of a stable yak products marketing system could be helpful.
3. There are some traditional technologies to process yak raw materials (meat, milk, leather, wool, bones etc.). However, there is need to develop modern, progressive technologies to process ecologically clean yak raw materials to produce modern products to meet market demands.
4. Modern progressive technologies to process ecologically clean yak raw materials to produce modern products need equipment and machinery. Most of these may need to be imported, a process which calls for the involvement of private entrepreneurs—industrial enterprises and companies.
5. It is extremely important to establish yak raw materials processing enterprises not far from the yak breeding regions so as to create jobs, increase income of mountainous regions, develop marketing and social infrastructure and so on. This would have a positive impact on the living standards of people in the yak-rearing areas.

In the context of the National Yak Development Program we would like to present to different donor organisations components of the complex project so as to get financial support. These components include a programme for the development of pedigreed yak herds, establishment of a non-governmental organisation dealing with yak development at the national level, and training programmes for yak farmers on methods of breeding and production of yak products, scientific programme on developing the standards for high quality yak products for domestic and international markets, and a programme to develop a market system for yak products.

The characteristics and problems of leather making with yak hide

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Summary

This paper discusses the characteristics and problems of leather making with yak hide. The paper addresses the following issues: histological structure of the hide, defects of the raw hide, the key techniques of leather making with yak hide, and the essential special leather chemicals.

Keywords: Characteristic, hide, leather making, problems, yak

Introduction

There are about 14 million head of yak in China, constituting 90% of the global yak population. The yak rearing area in China covers Qinghai, Tibet, Sichuan, Gansu, Xinjiang, Inner Mongolia and Yunnan Provinces. The yak hide is one of the main sources of raw hide for the manufacture of leather. The annual production of yak raw hide is estimated at more than 1.5 million hides.

Early in 1950s, the yak raw hide was used to make leather in Sichuan and Qinghai. With almost half-century of experience, the leather making techniques have developed considerably. In some areas such as Ya'an, Aba, Ruoergai of Sichuan Province, Xining of Qinghai Province, Lanzhou of Gansu Province and Lhasa of Tibet, there are some tanneries able to make a large number of products from yak hide. These include corrected grain leather, shoe upper leather and garment leather. However, the utility of yak hide is, to date, not sufficiently developed. Not many high quality products of yak leather are available in the market.

In this review, the characteristics and problems of leather making with yak hide are discussed. A major purpose of the review is to promote the development of yak hide tanning processes.

Defects and histological structure of yak hide

In China, the yak hide is produced mainly in the south-western and north-western cold highland areas, especially in the minority nationality regions. Because of the backward economies and the difficulties in transport, natural (air) drying is the current preservation

method used for most yak hides in these areas. One of the consequences of this is the prevalence of a hide defect known as dry-crack, which accounts for 55% of all defects. The second defect is hide rot and insect damage, which are 21 and 14% of all defects, respectively. To solve these problems, the use of salt-curing as a preservation method is suggested. The proportion of defects associated with this method is only 29%, compared with air-drying (Gao 1992).

Another defect of the hide is warble hole caused by warble fly infection. This causes damage to quality of a large number of hides. There is hardly any hide not infected. The damage caused by the warble fly consists of holes covering 6% of the whole hide. Fortunately, there are methods to prevent damage by warble, and these have been applied with much success. The hide damage can be successfully reduced; it is possible to make higher-grade leather with the yak hide. Another aspect related to the improvement of quality of leather products from yak hide has to do with the histological structure of yak hide. Huang (1992) studied this aspect. The results show that the yak hide has a dense cover of long hair. The sebaceous (fat glands) and the sweat glands in the hide are fairly developed and are present in large numbers. The hide is characterised by a great differentiation between the papillary layer (grain layer) and the reticular layer. The thin collagen fibres in the papillary layer of the hide are compactly woven, but the reticular layer is much looser. Therefore, to produce high quality soft leather from yak hide, the hair roots in the papillary layer should be removed as completely as possible and the differences between the two layers should be eliminated or reduced and more attention should be paid to removing the rich fatty materials from the sebaceous glands.

Key techniques of leather making with yak hide

The special problems summarised above in terms of defects and, most specifically the histological structures of yak hide aside, the leather making processes based on yak hide are similar to leather making with cattle hide. The processes of making shoe upper leather from yak hide is as follows: soaking, fleshing, degreasing, de-hairing and liming, re-fleshing, splitting of pelt, de-liming, bating, chrome tanning, splitting blue, shaving, re-tanning, neutralising, dyeing and fat-liquoring, filling, drying, dewing, vibration staking, coating finish, ironing, grinding, measuring and storing. Degreasing is a very important process in the case of yak hide because the sebaceous glands of yak are very well-developed; degreasing affects the processes that follow, and, if not done properly, may cause the cracks of the rain on finished leather. For the same reason, it is important for leather making with yak hides that the processes of de-hairing and liming are carried out with great care. The new technology of de-hairing with enzyme, sodium sulphide and sodium hydrosulphide is very effective and should be used whenever possible.

Development of special leather chemicals for yak hide

One has to contend with the natural defects of yak raw hide. However, it is also easy to cause defects if the hide is not properly processed. For example, loose grain, surface-crack can easily be caused by defective or poor processing. Therefore, it is important to consider the development of special leather chemicals for yak hides while, at the same time, the leather making processes are studied continuously and improved. To solve the problem of loose grain, it is necessary to do the filling with SCC acrylic emulsion filler and/or MSF micro-latex filler. The filler penetrates into the region between the grain layer and the reticular layer, thereby helping to stick the two layers together.

The yak raw hide has inherent defects and man-made scars. To increase the grade of the leather, ending agent is widely used in the coating finish. Through the mending and the mechanical processes, buffing and pebbling, a perfect result can be obtained.

Closing remarks

Yak hide is an important natural resource in China and must be utilised sufficiently. It is important to develop the economies of the minority nationality regions and to improve the tanning industry in these areas.

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Processing and use of yak slaughter by-products

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Summary

Due to economic limitations, the processing and use of by-products, including blood, internal organs, bone and waste hair from slaughtered yak, have not been fully attempted. However, previous reports have shown that medicines and other biochemical products could be extracted from these by-products. Slaughter by-products can also be made into feeds and feed additives for livestock and poultry. These can improve the overall economic value of the yak.

Keywords: By-product, development, slaughtered yak, use

Introduction

Numbering some 13 million head, the yak is a special livestock on the Qinghai-Tibetan Plateau and its surroundings covering total grassland of 3 million km² (Lu 1994). Yak is also the main production resource and life support for the people living in this area.

A development focus on the yak therefore provides an important avenue for addressing the needs of the people. However, because of the obstacles imposed by the natural environment and economic factors over a long period of time, the use of yak products, especially the intensive processing of the slaughter by-products, is still very limited. A small proportion of these by-products has been processed and sold as primitive materials at very low prices. It is estimated that, if all such by-products could be used effectively, one slaughtered yak could contribute an extra of 100 RMB Yuan (US\$ 1 = 8.2 Yuan). This would significantly increase the overall economic value of the highland livestock production system, with important implications for the living conditions of local herders. This paper reviews the possible uses of the by-products of slaughtered yak.

Products from yak blood

It has been shown that some valuable biochemical substances such as haemoglobin and super oxide dismutase (SOD) can be extracted from yak blood leaving the rest of the product to be made into blood and protein meal.

Yak serum

The serum albumin can be separated from the yak serum (Yang et al. 1988; Chen 1990). The albumin of cattle has been used in medicine as a biochemical reagent. Compared with the method of ammonium sulphate and salt extraction, the albumin from yak serum produced by the cold alcohol procedure had a larger quantity and a higher quality (after α -globin had separated). Furthermore, because the procedure is simple, low-cost protocols could easily be developed and applied in pastoral areas.

Blood cell plasma

Haemoglobin and SOD are important substances in erythrocyte. Hematochrome affects the cell's respiratory, biological oxidation and metabolism of the intro-organism. It is also widely used in the domestic and international markets as the main medical composition of anticancer drugs. SOD is a kind of metal enzyme, which could eliminate a super-oxygen anion (O_2^-). It has functions of antiphlogistics, hemostasis and prevents cells from aging.

A simple protocol for extracting hematochroma by the 'acetone method' from yak blood has been developed with a product yield of 3.2–4.0 g per litre (Yu and Zhang 1991). SOD had also been extracted from yak blood with a yield of 1g per 15 to 20 L (Yu and Zhang 1990; Hua et al. 1991; Xu 1991). It has been reported that the SOD obtained from yak blood not only has higher vitality, but also has higher purity than that from the blood of other animals, probably due to the low oxygen tension in the yak environment.

Yak blood cell plasma has also been manufactured into blood meal and fermented blood meal. The blood meal contained high quality animal protein and essential amino acids. The protein was up to 80% of the whole blood meal with a higher nutritive value than meat meal and fish meal (Yu and Zhang 1990). Thus, the blood meal of yak could be a very important raw material in the compound feed. The palatability of fermented blood meal is also quite high. Because of the simple processing techniques, the blood meal and fermented blood meal can be manufactured even in a small slaughterhouse. Livestock in pastoral areas can, thus, make use of the blood meal obtained from the waste blood of yak as a supplementary source of protein.

Brewing soy sauce from the yak blood

Brewing soy sauce from the yak blood is a new way to produce food additive using yak slaughter by-products (Yang and Zhang 1988). Through proper sanitary and physiochemical screening, the soy sauce from yak blood can be produced that meets the required food standards. Moreover, it contains larger quantity of free amino acids. Because there is more glutamic acid in the yak blood soy sauce than in the soybean soy itself; the yak blood soy is sweeter.

Biochemicals extracted from the yak viscera

Cytochrome C

Applying the protocol used in pig, the cytochrome C has been successfully extracted from fresh or frozen yak heart (Yang et al. 1989). The yield was up to 135.0417 ± 5.3751 mg per kg.

Heparin

Semi-finished product of heparin can be extracted from the lungs and small intestines of yak by the salt lyses and ion exchange method (Yang et al. 1989; Zhang et al. 1991). The yield was up to 43,416.87 U per kg milled lung. The average anticoagulant effect was 81.94 U/mg, which met the national standard (>80 U/mg).

Bilirubin

Bilirubin is the major part of natural bezoar and it can be extracted from bile collected from either a living or slaughtered animal (Zhang et al. 1989; Wang et al. 1992).

Uses of bone and waste hair

Besides the use in the making of elegant crafts, the yak bone is used to extract bone gelatin and bone fat or to process bone meal and jam. These substances can be further made into health foods or the feed supplements both of which are in great demand in the domestic and international markets because they are rich in phosphorus, calcium, and proteins (Zhang et al. 1989).

There are 18 amino acids in the yak hair, of which cystine makes up 7–10% of the total. It is possible to extract the cystine from the wasted yak hair in textile industry, which can be used as additive in chemistry and feed supplement (Kuang and Zhao 1997).

Closing remarks

It has been said that all parts of yak have high value. However, the problem is how to develop and use them efficiently. The use of the meat, milk, hide, wool and undercoat of yak has been fairly popular and successful, but large-scale processing is still not developed. Not only does non-use of these by-products represent an economic loss, it also presents a problem to environmental health when these products are discarded following slaughter. These products should be further processed and marketed. Both research and development are needed to make this possible.

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Summaries and recommendation

Summaries and recommendation

Technical papers cover specialised topics under the following themes:

- Session I: Pastoral production systems in yak rearing areas
- Session II: Genetic diversity of wild and domestic yak: Conservation and management
- Session III: Nutrition and forage management
- Session IV: Reproduction and breeding
- Session V: Environmental physiology
- Session VI: Diseases and health services
- Session VII: Yak products and their processing and marketing

Session I: Pastoral production systems in yak rearing areas

Chairpersons: Ms Camille Richard, Drs Abdul Wahid Jasra and Zhang Degang

Session I addressed a broad range of considerations which impact pastoral production systems in yak rearing areas, including social, economic and environmental factors. Many of the papers recognised that these systems are concerned with more than just livestock production, and stressed the need for a more interdisciplinary approach to pastoral development. Participants emphasised that alternative livelihood strategies need to be considered as a means for improving the living standards of local people.

Socio-economic factors that specifically affect both human and yak demographics were discussed. In some areas, for example, external factors, such as increased government control over land resources in protected areas, and/or alternative livelihood options such as tourism, have caused new constraints on traditional systems resulting in declining human and yak populations in some areas. In other cases, collapsing local economies (e.g. in the Central Asian States) have led to a rise in yak numbers, mainly because yak (intrinsicly a multi-purpose animal) are known by local people to provide a solid subsistence base.

Most of the papers illustrated how issues, which impede development in pastoral areas, are often social rather than technical in nature. In fact, technical interventions are usually not adopted unless and until the socio-cultural and economic situation is understood and appreciated. Some papers highlighted the rapid changes in political boundaries and policies that have led to restricted livestock mobility and the marginalisation of pastoral people, pointing out that such changes need to be understood in order to identify realistic strategies for livestock and rangeland development. It was also mentioned that mechanisms need to be considered which will ensure secure tenure, both within and across borders.

Other papers noted how land management policies in general are often not responsive to local conditions in yak rearing areas. One paper described the interactive effects of climate and grazing on alpine pastures, indicating that while livestock are often blamed for declining rangeland productivity, the situation is much more complex. Current policies may

not adequately address this fact, however, which highlights the need to develop more appropriate policies based on accurate and up-to-date research. Greater stakeholder involvement (primarily of local herders and farmers) is also needed in the decision-making process.

Congress participants also raised the point that scientists themselves need to listen to herders, and stressed that more effective means of communicating research results to those most directly affected need to be devised. They also noted the need to recognise the aspirations of local people in efforts to maintain the integrity of mobile livestock systems. Future research and/or policy recommendations:

- More research is needed to substantiate the rhetoric of overgrazing. For example, we need to investigate more thoroughly the cumulative and interactive effects of climatic change and grazing on the Tibetan Plateau. Although this interaction is still poorly understood, climate change itself may trigger and account for rangeland productivity decline more than increasing livestock numbers and overgrazing. More quantitative research is also needed to substantiate the impacts of livestock on forest regeneration.
- Recognising that policies, which restrict the traditional movements of pastoralists and their herds, have triggered rangeland degradation in at least some areas, historical research is needed which investigates the impact of policy change on pastoral regions.
- The impacts of local, regional and international market forces on local communities need to be documented, in terms of factors such as labour and migration patterns, movement of goods, and the economic and social control of trade.
- There is an intrinsic link between culture and the way local people perceive and manage their land and livestock. Indigenous knowledge of livestock and rangelands must be documented and integrated into current research programmes, as a basis for prioritising future technology and policy development in pastoral regions. Indigenous knowledge systems also need to be more fully understood, appreciated, respected and incorporated into policy decision-making.
- There is a need to change the way we do research and development, from highly technical to interdisciplinary, from exclusive to inclusive, so that research is conducted with the full participation of farmers and herders. This will help facilitate understanding at the local level, and help establish an inter-cultural dialogue that facilitates effective extension and technology transfer. This type of approach seeks to find a means of basing future innovations on indigenous knowledge wherever possible, to help ensure that technologies are appropriate and sustainable at the local level.

Session II: Genetic diversity of wild and domestic yak—Conservation and management

Chairpersons: Dr Olivier Hanotte, Mr David Steane and Dr Han Jianlin

Session II focused on the biological factors which affect the conservation and management of yak populations, specifically in terms of their genetic potential and limitations. It was noted that studies addressing yak diversity using protein and DNA

markers are now well under way, though unfortunately the usefulness of some of this work has been limited by less than adequate sample sizes and methodologies. There is a clear need for more research on all breeding populations if we are to develop optimal strategies for their management. Classical quantitative genetics will continue to be the major method for any genetic change made in the short to medium term (10–20 years), with molecular genetics complementing rather than replacing these efforts.

Future research and/or policy recommendations:

- All molecular genetics work (DNA and protein) on yak should be co-ordinated, starting with the standardisation of sampling procedures and methodological guidelines. Participants recommended that Mr David Steane and Dr Olivier Hanotte initially be contacted in this regard. A standard set of molecular markers of references should also be defined and included in every study.
- Biological samples should be exchanged both within and between countries, following the principles outlined by the Convention on Biological Diversity. An international centre such as ILRI can help facilitate this process, and at the same time provide international recognition of individual country abilities and contributions.
- There is a need for more phenotypic and environmental (including management) data, to be obtained and made available through central databanks such as Food and Agricultural Organization of the United Nations–Domestic Animals Diversity Information Service (FAO–DADIS) and International Yak Information Centre (IYIC).
- To facilitate the proposals outlined above, a national co-ordinating group, which might include the existing national co-ordinators of animal genetic resources (AnGR), could be formed to cover all aspects relevant to the yak industry.

Session III: Nutrition and forage management

Chairpersons: Dr James Robinson, Mr Laurens Wester and Dr Zheng Yucai

This session focused on nutrition and forage management in yak rearing areas. More specifically, issues related to rangeland quality, the nutritive values of both native forages and supplementary feeds, and the importance and role of technology and indigenous knowledge were addressed.

Participants agreed that yak nutrition remains primarily dependent on natural forages in high mountain areas. Because of this, it was stressed that the carrying capacity of these rangelands must not be exceeded. Several papers highlighted the important role that shrubs can play in maintaining yak nutrition, particularly towards the end of summer when other natural feed varieties have been exhausted. Another stressed the fact that yak are fundamentally well adapted to their environment, pointing out that weight loss over the winter is a perfectly natural and acceptable phenomenon. The author questioned the necessity of supplemental feed sources given that most yak survive sufficiently on reserves built up over the summer on natural forage alone.

The practice of reseeding as a means of protecting rangeland resources was also discussed. One author stated that reseeding should be seen as a last resort, and should be considered only after other methods have been explored and tried first. He pointed out that

appropriate technology for reseeding degraded rangeland is not available which herders themselves can apply. The technologies currently proposed require large machinery, and thus are out of reach of herders in Qinghai, for example, who often do not even have the money to buy seed. Another participant, noting that in Bangladesh at least, poor people have a high pay back rate, urged that microcredit schemes be considered to facilitate the introduction of appropriate technologies.

The importance of identifying and working with indigenous indicators of rangeland conditions was also mentioned. The person commented that outsiders are more likely to select erroneous indicators of rangeland conditions than are locals, which is why we should begin with indigenous indicators first. Another participant pointed out that science does not necessarily have all the solutions, and again stressed the importance of first learning what communities have been doing for centuries in these areas.

As in earlier sessions, participants also stressed the importance of sharing research results internationally. By way of example, one participant noted that protozoa are being discovered in other parts of the world that can detoxify plant poisons, a discovery which might prove useful for yak production in the future.

Future research and/or policy recommendations:

- There is a need to assess the cost-benefits of supplemental feeding, including that done over part of the winter only. More specifically, there is a need to quantify the effects of feeding urea-treated straw in winter and compare these with the effects of regular straw.
- There is a need to quantify the changes in protozoa over the course of the year, and to correlate these with feed intake and body weight, and changes resulting from different feeds.
- Standard measures for both rangeland quality and the nutritional condition of yak need to be adopted, which are both scientifically valid and applicable over vast and often diverse areas where yak range.
- Appropriate technology must be used to restore deteriorated rangeland to enhance the digestive efficiency of yak, and to provide supplementary feed, with the goal of enhancing yak survival over the winter months and productivity in the following year.
- Indigenous knowledge must be taken into account when doing research to ensure that technologies used are appropriate. There is also a need to popularise introduced technologies and to facilitate their adoption through microcredit opportunities.
- To facilitate informed decision making, there is a need to gather more quantitative data on yak production systems, and to generate a base for monitoring trends.

Session IV: Reproduction and breeding

Chairpersons: Drs Ed Rege, Michael Goe and Zhao Xinbo

This session covered a broad area of topics related to reproduction, yak breeding and the yak production system, and included reports on yak evaluation studies and the status of yak populations as affected by changing economic and farming environments. Papers related to yak breeding covered phenotypic characterisation and aspects of genetic improvement—both within breed selection and crossbreeding involving different yak

breeds, and hybridisation of yak and cattle. Papers on reproduction covered both male and female reproductive performance, including artificial insemination (AI), the effects of freezing and thawing semen, and aspects of semen sexing. A large number of published but not presented abstracts, some of which were referred to during the discussions, complemented the presented papers.

Both the papers and the ensuing discussions revealed that there is clearly an opportunity for crossing domestic yak with its wild relative. In fact, yak herders are already doing this routinely in some areas. However, the specific gains from such breeding systems have not yet been systematically quantified.

Crossbreeding among domestic yak populations was also discussed. However, the fact that this is happening in the absence of genetic and phenotypic characterisation data on the different yak populations involved highlighted the urgent need for yak populations to be characterised immediately.

The discussion also touched on possible gains to be had from cross-species hybridisation, specifically between yak and cattle. Two points were raised in this regard. First, there is a need to ensure that the practice does not deteriorate the traits of the breed—the situation now facing other species (e.g. cattle), where, because of a preference for crossbreeds, the less numerous indigenous populations have now become threatened. Second, it is important that the practice not be undertaken as a single path to genetic improvement, i.e. ignoring the characterisation and development of the yak resource itself.

Although the papers presented mainly focused on ‘conventional’ economic traits—reproductive traits, milk, meat (growth)—participants felt it was important to consider the aggregate genotype of yak in the development of yak breeding programmes. These should include the whole set of traits considered important by yak herders. Adaptive fitness in relation to the yak environment, transport (pack) function, fur yield and quality were some of the traits mentioned. It was noted that the future of yak would depend on their continued ability to survive in difficult—but increasingly changing—environments. Successful competition of yak products in a world of ‘cheaper alternatives’ will require the identification and promotion of an array of unique and exceptional high quality products, including a focus on ‘niche’ markets that will provide improved livelihoods to yak keepers. The issue concerning whether there is a real need to breed yak for increased body size—especially in view of the possibility of their becoming less adaptive in the process—was raised but not discussed conclusively.

Several papers raised the question of inbreeding as a possible problem for some yak populations in the region, but conflicting conclusions were suggested. Although there are differences between the various yak populations, none of the studies were of sufficient scope and design to provide compelling results in this regard. In view of the current belief that inbreeding is a problem for many yak populations in isolated areas, this issue needs to be addressed urgently by researchers. In the meantime, the practice of facilitating the exchange of bulls among herders should be promoted.

The yak is a seasonal breeder, and its peak-breeding season coincides with the time it resides in higher altitude areas—beyond the reach of extension agents. Consequently, attempts to use AI in yak have not been very successful. Thus, natural mating will remain the method of choice in yak breeding for the foreseeable future.

The need for an appropriate recording system for yak came out very strongly. A suggested set of measurements to be taken was presented. Although this was not discussed at length in the ensuing discussions, it presents a good starting point. One area that needs to be addressed is how such a recording system could be implemented (or simplified) given the mobility of the yak herds and the fact that most herders are illiterate. The benefits of recording, as pointed out, go beyond breeding and genetic improvement; improvement in herd management is probably the biggest and most immediate benefit of herd recording.

There is a big move towards high-tech molecular characterisation. Many countries, however, lamented that they do not have sufficient physical and human resources to undertake such characterisation on their own. The need for regional networking in this area became quite obvious and was emphasised. Additionally, some papers presented quite useful results from biochemical (principally protein polymorphism) analyses and phenotypic data—based on multivariate (principal component) analyses of linear and other body measurements. These techniques still have a role to play in breed characterisation, and should be applied in lieu of, or as a complement to, microsatellite or other DNA-based approaches.

One paper in the session presented some preliminary results on superovulation in yak. Another presented work on efficient production of transgenic bovine and cat embryos by microinjection and cloning—with implications for yak. Whereas these technologies, especially superovulation and embryo transfer, could possibly play an important role in *ex-situ* conservation of yak, they do not have an immediate application in commercial yak production. Unfortunately, because of time constraints, these two papers were among those not discussed in sufficient detail.

Future research and/or policy recommendations:

- Genetic and phenotypic characterisation of existing yak populations is urgently needed.
- More research is needed on the question of inbreeding within yak populations, particularly those located in remote, isolated areas.
- An appropriate recording system for yak needs to be developed and standardised.
- There is a need for regional networking, particularly concerning high-tech molecular characterisation.
- Unique and exceptional high quality yak products need to be identified and promoted, as do the specialised ‘niche’ markets where they can be sold.

Session V: Environmental physiology

Chairpersons: Drs Eijin Han and Luo Xiaolin

This session focused on issues related to environmental physiology. Though it is well known that yak are well adapted to cold climates and high altitudes, and do not readily endure adverse environments such as those with high temperatures, one paper showed that at least some yak in North America are being raised in low elevation areas with warm climates for much of the year. These animals are said to be doing well.

Another paper described how adult yak at about 3000 metres above sea level displayed different physiological responses between seasons, namely the cold-humid (mean daily

temperature $4.7 \pm 2.3^{\circ}\text{C}$, and mean daily relative humidity of $74.5 \pm 3.9\%$) and moderately cold-humid (mean daily temperature $18.1 \pm 0.3^{\circ}\text{C}$, and mean daily relative humidity of $74.2 \pm 2.5\%$). Using a Daily Search Index, it was found that yak lack thermoadaptability during the moderately cold season.

Another paper suggested that the crossbreeding of wild and domestic yak would be a useful tool for improving the productivity of yak in southern Qinghai Province.

Session VI: Diseases and health services

Chairpersons: Drs Peter J. Waller, Lham Tshering and Hu Songhua

This session looked at health-related issues, such as diseases, which afflict yak and health services available to them. Specifically, the papers presented covered parasitic infections, bacterial infections, drug susceptibility testing, serological surveys, bovine mastitis and community animal health workers.

Future research and/or policy recommendations:

- Improved health care needs to be provided to yak to improve their productivity.
- Epidemiological surveillance of diseases afflicting yak need to be carried out.

Session VII: Yak products and their processing and marketing

Chairpersons: Drs Kulsina Kachkynbaeva and Han Jianlin

This session focused on the processing and marketing of yak products. Participants underlined the importance of developing raw material and different yak products processing for market. In particular, great attention was paid to meat, milk and butter processing and marketing, as well as leather and hair. Studies indicated that the processing and wide marketing of yak products could serve to improve the health of people and help to realise the sustainable development of the yak rearing regions of the world.

Future research and/or policy recommendations:

- Further research and practical activities devoted to the investigation of all kinds of yak products and raw materials (food and non-food ones) are required to enhance the profitability of yak breeding and to promote the economic and social development of yak rearing regions.
- Greater co-operation is needed for investigating, processing and marketing specific raw materials such as blood to produce high quality plasma and insulin; organs of internal secretion to produce valuable medicines to cure diseases; and horns and hooves to produce extremely valuable medicines to cure such serious diseases as cancer and contagious infectious disease (CID).
- Co-operation is needed to develop international standards for yak products and to enlarge international market systems. This will help both to promote the development of yak rearing countries, and to supply as many countries as possible with ecologically sound and valuable goods.

Third International Congress on Yak

4–9 September 2000, Lhasa, Tibet, P.R. China

The Third International Yak Congress was held from 4–9 September 2000 in Lhasa, Tibetan Autonomous Region (TAR) of P.R. China. The aim of the meeting was to provide a forum for delegates from yak-raising and non-yak-raising countries to explore multidisciplinary aspects and approaches to sustainable yak production on the high altitude rangelands of the Central Asian Region, to exchange scientific information, to deepen mutual friendship, and to strengthen co-operation. It was the third time that the congress was held in P.R. China, the most important yak rearing country, following the conferences in Lanzhou (Gansu, August 1994) and in Xining (Qinghai, September 1997). With the permissions from the State Administrations of Science and Technology, Agriculture and Foreign Affairs, and the TAR Government, the Tibetan Academy of Agricultural and Animal Sciences of TAR (TAAAS), the Department of Agriculture and Animal Husbandry of the TAR, the Department of Science and Technology of the TAR and the Foreign Affairs Office of TAR worked for the preparation of the meeting under full co-operation from the International Yak Information Centre (IYIC), the International Centre for Integrated Mountain Development (ICIMOD), the International Livestock Research Institute (ILRI), the Food and Agricultural Organization of the United Nations–Regional Office for Asia and the Pacific (FAO–ROAP) and the Yak and Camel Foundation of Germany.

Hosts

National organising committee

- Tibetan Academy of Agriculture and Animal Sciences of the Tibetan Autonomous Region (TAR) (TAAAS)
- Department of Agriculture and Animal Husbandry of TAR
- Department of Science and Technology of TAR
- Foreign Affairs Office of TAR
- China Yak Breeding Association

National sponsors

- People's Government of TAR
- Heifer Project International, China Office (Sichuan)
- Qinghai Academy of Animal and Veterinary Sciences
- Datong Yak Farm

International organisers

- International Yak Information Centre (IYIC)
- International Centre for Integrated Mountain Development (ICIMOD)
- International Livestock Research Institute (ILRI)
- Food and Agricultural Organization of the United Nations–Regional Office for Asia and the Pacific (FAO–ROAP)

International sponsors

- Food and Agricultural Organization of the United Nations–Regional Office for Asia and the Pacific (FAO–ROAP)
- International Centre for Integrated Mountain Development (ICIMOD)
- International Livestock Research Institute (ILRI)
- The Yak and Camel Foundation of Germany
- Kyrgyz Swiss Agricultural Project (KSAP), Helvetas, Kyrgyzstan
- Royal Netherlands Government Embassy to P.R. China, Beijing
- Canadian International Development Agency (CIDA), Beijing

Congress symposia themes

Symposia will be held to highlight the following major themes of the Congress:

- Pastoral production systems in yak-rearing areas, focusing on the cultural and ecological importance of yak for sustainable livelihoods and economic development on the Tibetan Plateau (hosted by ICIMOD). Papers are invited to cover multi-disciplinary aspects, such as agro-ecology of pastoral areas, culture, policy and economics.
- Genetic diversity of wild and domestic yak: conservation and management (hosted by FAO–ROAP and ILRI). Papers are invited to cover all aspects of conservation, including yak–wildlife interactions and protected area management, as long as it relates to the preservation of yak and associated pastoral livelihoods.

Technical sessions

Technical papers are invited to cover specialised topics along the following themes:

- Reproduction and breeding
- Nutrition and forage management
- Environmental physiology
- Diseases and health services (including traditional medicine)
- Yak products and their processing and marketing

Organising Committee for the Third International Congress on Yak

Lhasa, Tibet, P.R. China, 4–9 September 2000

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Programme of the Third International Congress on Yak

4–9 September 2000, Lhasa, Tibet, P.R. China, Chairpersons: Ms Camille Richard, Drs Abdul Wahid Jasra and Zhang Degang

3 September 20:00	<i>First Meeting of the Members of the Organising Committee</i> Chairperson: Prof Wei Xuecheng Secretary: Dr Han Jianlin
4 September 9:00–10:30	<i>Opening Ceremony: Chairperson: Mr Wang Chengjie</i> (Director, Department of Agriculture and Animal Husbandry of the Tibetan Autonomous Region (TAR), P.R. China) <i>Opening Speeches: Mr Gyalbu</i> (Vice Governor, People's Government of TAR, P.R. China) Mr Chen Zhenrong (President, Tibetan Academy of Agricultural and Animal Sciences of TAR, P.R. China) Dr Denis Hoffmann (Representative of FAO-ROAP) Dr Horst E. Geilhausen (Representative of Yak and Camel Foundation in Germany) Dr James Gabriel Campbell (Director General, ICIMOD)
10:30–11:30	<i>Visit to the yak products exhibition</i>
11:30–12:30	Chairpersons: Drs Gerald Wiener and Nyima Tashi
Special Session	<i>Speakers</i> Mr Wang Wenpei, 'Brief introduction to agricultural and animal husbandry development in Tibetan Autonomous Region' Dr Corneille Jest, 'Towards a global approach to the study of yak research and development' Ms Camille Richard, 'The potential for rangeland development in yak rearing areas of the Tibetan Plateau'
14:30–17:30	Chairpersons: Ms Camille Richard, Drs Abdul Wahid Jasra and Zhang Degang
Pastoral production systems in yak-rearing areas	<i>Speakers:</i> Julia Klein, 'Climatic and grazing controls on vegetative aboveground biomass: Implications for the rangelands on the north-eastern Tibetan Plateau' Hermann Kreuzmann, 'Recent results of yak research in Western High Asia'

		Li Quan, 'Discuss on yak sustainable development in southern Qinghai Province'
		Satrughan Lal Pradhan, 'Yak crossbred production in the central Upper Slope Region of Nepal: A community resource management strategy in the Central Upper Slope'
		Xie Hongyan, 'Current rangeland management in Zhongdian County, Diqing Tibetan Autonomous Prefecture, north-western Yunnan, China'
		Rita Merkle, 'Nomadism: A socio-ecological mode of culture'
		Wolfgang Holzner, 'Integrative agro-ecological investigations of the pastures the TAR, China'
		Ken Bauer, 'The cultural ecology of yak production in Dolpo, West Nepal, with comments on the prospects for sustainable pastoral livelihoods and economic development in the western Himalaya'
	19:30	Greeting Banquet
		Chairperson, Mr Zhou Chunlai (Vice General Secretary, People's Government of TAR, P.R. China)
		Greeting, Mr Gyalbu (Vice Governor, People's Government of TAR, P.R. China)
5 September		Chairpersons: Dr Olivier Hanotte, Mr David Steane and Dr Han Jianlin
	9:00-12:30	<i>Speakers:</i>
Genetic diversity of wild and domestic yak: conservation and management		Jillian F. Bailey, 'Genetic variation of mitochondrial DNA within domestic yak populations'
		Olivier Hanotte, 'Low level of cattle introgression in yak populations from Bhutan and China: Evidences from Y-specific microsatellites and mitochondrial DNA markers'
		Tashi Dorji, 'Genetic diversity in Bhutanese yak (<i>Poephagus grunneins</i>) populations using microsatellite markers'
		Gerald Wiener, 'Opportunities for the improvement of yak production with particular reference to genetic options'
		Qi Xuebin, 'Genetic variations of yak in Gansu: Inferred from their milk protein polymorphisms'
		Han Kai, 'Crisis leading to decline of wild yak and issues for their protection and utilisation'
		Zheng Yucai, 'Milk protein genetic polymorphism: A comparison between Maiwa yak and Jiulong yak'
		Fan Baoliang, 'Cloning and sequencing of the 5' -flanking region of kappa casein gene in yak'.

5 September	Chairpersons: Drs Ed Rege, Michael Goe and Zhao Xinbo
	Speakers:
14:30–18:00	Michael R. Goe, ‘Monitoring of traits for yak and yak–cattle crosses’
Reproduction and breeding	Zhong Jincheng, ‘Analysis of main component about several breeding traits of Maiwa yak’
	T. Suzuki, ‘Efficient production of transgenic bovine/cat by microinjection and cloning technology of early embryos’
	Yun Den, ‘Effects of selection and breeding on yak within breeds in Linzhou Yak Breeding Farm’
	M. Kasmaliev, ‘Efficient ways for the increases of yak numbers and their production’
	Chen Jingb, ‘Review of the development of Bayingolin yak’
	Ji Qiumei, ‘Present situation and resource of yak production and reasons for degeneration of Tibetan yak productive performances’
	A. Magash, ‘The preliminary experiment to induce superovulation in female yak’
	Andras Kovacs, ‘Light microscopic investigations on frozen–thawed yak semen—A pilot study’
	Andras Kovacs, ‘Experiments on sexing yak spermatozoa by fluorescent <i>in-situ</i> hybridisation using bovine Y–chromosome specific DNA probe’
	Yan Shoudong, ‘A study on the improvement of yak reproductive performance by introducing wild yak blood’
	L. Tshering, ‘Artificial insemination trial in yak in Bhutan’
19:10	Tibetan Art Performances at Haisha Auditoria by Nationality Art Group of Lhasa City.
	Speech: Mr Luosang Jiangcun (Mayor, Lhasa City, TAR, P.R. China)
6 September	Chairpersons: Drs Peter J. Waller, Lham Tshering and Hu Songhua
9:00–12:30	Speakers:
Diseases and health services	Peter J. Waller, ‘Reindeer (<i>Rangifer tarandus</i>) and yak (<i>Bos (Poephagus) grunniens</i>): Disparate animal species—Similar environment, management and parasite problems’
	Tian Yun, ‘Drug susceptibility test of <i>E. coli</i> isolates from healthy yak of Qinghai’
	Horst E. Geilhausen, ‘Serological survey on infectious diseases of a White yak herd in the Gansu Province’
	Hu Songhua, ‘Treatment of bovine mastitis with medicinal herbs and acupuncture’

6 September	Karin Persson Waller, 'Mastitis control in ruminants'
14:30-18:00	Zeng Qionghui, 'Test of enterotoxigenicity of <i>E. coli</i> from yak'
Nutrition and forage management	Horber Peter: 'The contribution of community animal health worker's (CAHW's) to an efficient animal health management system'
	Durga Datt Joshi, 'Impact of national parks and tourism on yak farming system in the Alpine Himalayan Region of Nepal'
	Chairpersons: Drs James Robinson, Laurens Wester and Zheng Yucai
	<i>Speakers:</i>
	Walter Roder, 'Grazing resources for yak production systems in Bhutan'
	Barbara Brower, 'Yak grazing and forest dynamics in Sagarmatha National Park, Nepal'
	Abdul Wahid Jasra, 'Yak pastoralism in Pakistan'
	W. Eric Limbach, 'Grass and legume variety trials in eastern Tibet'
	Long Ruijun, 'Availability and utilisation of shrubs as the protein sources for the yak grazing on alpine grass meadow of Tibetan Plateau, China'
	Laurens Wester, 'Production and use of an illustrated handbook for sheep and yak herders in Qinghai'
	Zhang Degang, 'Potential of alpine shrubs in Qilian Mountain Regions'
	R.N. Pal, 'Urea enriched finger millet (<i>Elensine coracana</i>) straw: Effect of feeding on yak'
	Gui Rong, 'Rumen ciliate protozoal fauna of yak (<i>Bos grunniens</i>) in China with the description of <i>Entodinium monuo n.sp.</i> '
20:00	Poster session and free discussion
20:00	Second Meeting of the Members of the Organising Committee
	Chairperson: Prof Wei Xuecheng;
	Secretary: Dr Han Jianlin
7 September	Visiting Linzhou Yak Farm
Bus leave at 8:00	
8 September	Visiting Dangxiong Yak Farm
Bus leave at 7:00	
9 September 9:00-12:00	Visiting Potala Palace and Tibetan Museum

- 9 September
14:00–15:15
Yak products and their
processing and marketing
- Chairpersons: Drs Kulsina Kachkynbaeva and Han Jianlin
Speakers:
Ma Zhengchao, 'Development of yak veal and its related technology'
Bhu Chong, 'Beef production and quality of three fine yak breeds in Tibet of P.R. China'
K. Kachkynbaeva, 'Issues of development of yak products and their processing and marketing'
Braja K.P. Shaha, 'Economics of yak farming with relation to tourism in Nepal'
- 9 September
15:45–16:45
Environmental physiology
- Chairpersons: Drs Eijin Han and Luo Xiaolin
Speakers: Gerald Wiener, 'Adaptation of yak to non-typical environments: A preliminary survey of yak in North America'
Luo Xiaolin, 'Productivity of yak in southern Qinghai Province'
Mihir Sarkar, 'Physiological responses of yak under different environments'
- 9 September
17:00–18:30
Closure ceremony
- Chairperson: Mr Wang Wenpei (Deputy Director, Department of Agriculture and Animal Husbandry of TAR, P.R. China) Thanks note: Mr Nyima Tsering (Vice Governor, People's Government of TAR, P.R. China)
Dr Corneille Jest (Directeur de Recherche (Emeritus), Centre National de la Recherche Scientifique, Paris, France)
Prof Zhang Rongchang (Director, IYIC) Summaries and recommendations: Dr Han Jianlin (Executive Secretary, IYIC)

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Appendices

Opening addresses and remarks

Opening address, by Gyalbu

Respected chairman, distinguished delegates, ladies and gentlemen,

We are all very happy that the Third International Congress on Yak is being held today here in Lhasa. It is my great pleasure to be here on behalf of the People's Government of Tibetan Autonomous Region to express our sincere congratulations and our warmest welcome to all the delegates from various parts of the world and from sister provinces of China.

The Tibetan Autonomous Region (TAR) lies in the south-western part of P.R. China. It is the main body of the Qinghai-Tibetan Plateau with a total area of 1.2 million square kilometres occupying one-eighth of the total territory of P.R. China. With high and steep topography, the TAR has been known as the roof and the third pole of the world. More than 86% and 45% of the total land of the TAR have average altitudes higher than 4000 and 5000 meters above sea level (masl), respectively. High mountains with wide distribution and great variation in altitude result in great diversity in the region. There are 50 high mountains where the altitudes are above 7000 masl and another 11 with altitudes above 8000 masl. With unique topographical and geographical features that affect climate, biology and the soil, the TAR has formidable and unique landscape and sight. All these make the TAR quite different from other regions in terms of the tourism resources. The tourist sights are not only based on natural resources, but also the Tibetan culture, history and religion.

Within the great complexity of topography, surrounded by high mountains, steep slopes, alternated with mountains and lakes and great diversity of landscape, there are not only climatic zones ranging from tropical, subtropical and temperate to cool and cold zones, but also very apparent vertical distributions. As a result of this, there are rich biodiversity, mineral deposits and fresh water resources in the TAR. Studies concluded that the TAR has the highest number of animal species in China. Findings reported that there are 798 different amniotes in the TAR. The TAR is also one of the provinces in China, which has the richest forestry resources and the largest area of natural forestry. The TAR also has many lakes and rivers that provide considerable amount of fresh water resources. All these valuable resources have great potential to form a fundamental base to boost up the social and economic development of the TAR.

There are more than 30 different minorities, mostly Tibetans, in the TAR with a total population of 2.5 million. Despite the harsh and cold livelihood conditions, the hardworking and talented Tibetans have created a splendid culture from generation to generation since a long time back. I believe that with their warm hospitality, the honest Tibetans will give all of you a good impression.

The TAR is one of five largest pastoral areas in China. The great expansion of rangelands with a total area of 65 million hectare occupies 54% of the TAR landmass. At present, there is 59 million hectare of usable rangelands in the TAR. The remaining

rangelands are distributed in the high altitude areas with very cold climate. The strong radiation and great fluctuation in temperature from day to night provide a good condition for producing more and better quality grasses. Currently, the total number of livestock in the TAR is about 23 million. There are more than 4 million yak in the TAR, which comprise of more than 30% of the total number of the yak population in P.R. China. Breed diversity of yak is one of the most valuable resources for yak production in the TAR.

Recently, with overall guidance from the Planning Meeting on Tibetan Development of the Central China Government and with generous supports from sister provinces in China, the TAR has become further strengthened by adopting the 'open door' policy, implementing the strategy of accelerating development through promotion of science, technology and education, and accelerating infrastructure development. Thus, a notable progress in socio-economic development has been achieved. Now the living standard of the people is improving rapidly and the application of science and technology in agricultural development is increasing, particularly after implementing the policy of accelerating the development of western China. The socio-economic development of the TAR will certainly be further enhanced and will result in remarkable changes in future. Nevertheless, as one of the largest pastoral areas in China with a huge population of yak, we are still far behind in terms of development of yak husbandry, science and technology and in improvement and conservation of rangelands as compared to other developed countries and sister provinces. We need to learn to close these gaps. The Third International Congress on Yak, which is held here in the TAR, is a good opportunity for us to learn. The exchange of ideas among the delegates would provide us good experiences. I believe that it will further facilitate livestock development; particularly it will bring deep and positive effects on sustainable development of yak husbandry.

The 20th century has been a memorable one for the world. At the end of this century, looking back, the advancement in science and technology has promoted the progress and civilisation of human society. Science and technology is now closely linked with all aspects of development and livelihoods of people. Therefore, accepting and respecting science and technology and promoting these into a driving force of production are the urgent needs and wishes of all people. I believe that a successful organisation of the Third International Congress on Yak in Lhasa is not only a chance for learning and exchanging ideas, but also a great opportunity for all experts on yak to know each other and to strengthen collaboration with each other.

Respected delegates, ladies and gentlemen,

The month of September in Lhasa is pleasant. I would like to recommend you to go around and see some of the unique sights of the Plateau. Meanwhile, I would like to state that this is a good and a fast growing period of development for the TAR and we hope to bring into effect of the results of the policy for accelerating the development of western China. It will provide more and better opportunities for the TAR to develop further. Therefore, I hope that all the delegates and distinguished guests can enter into collaboration with us and invest in the TAR.

Finally, I sincerely wish for a successful congress. I wish all of you a happy and healthy stay in Lhasa.

Thank you!

Gyalbu
Vice Governor of People's Government of the Tibetan Autonomous Region
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Opening remarks, by Chen Zhenrong

Respected honourable chairman, distinguished delegates, ladies and gentlemen,

Based on the resolution of the Second International Congress on Yak held in Xining in 1997, the Third International Congress on Yak is being held in Lhasa in September 2000. The People's Government of the Tibetan Autonomous Region (TAR) has given a great importance to this congress and has requested the Tibetan Academy of Agricultural and Animal Sciences to organise the congress. Therefore, we feel privileged and have put much emphasis on it as a major activity of the Academy in the year 2000. To hold this congress successfully, an efficient preparation group was formed and all relevant tasks have been accomplished. Today, the Third International Congress on Yak is convening ceremoniously in Lhasa. I, on behalf of the Tibetan Academy of Agricultural and Animal Sciences, would like expressing our warmest welcome to all the distinguished delegates and guests.

As one of the five largest pastoral areas in China, the TAR has a long history of livestock development, which is important to the Tibetan people. In addition to the common characteristics, Tibetan livestock development also has the unique plateau speciality. The Central China Government, the Tibetan Departments and sister provinces have selected and sent many experts on animal husbandry and veterinary to work in the TAR. Meanwhile, many Tibetans have also been trained in China for further studies. Research and technology development have been improving step by step, and now there are professionals and technicians who are mainly local Tibetans. Many staff of livestock related institutions have specialised in animal husbandry and veterinary to overcome a lot of difficulties such as the harsh natural environments and poor living conditions. These professionals and technicians have achieved marvellous accomplishments after long and hard work.

Because of some major limitations, such as high elevation, cold weather, lack of oxygen and harsh conditions, there are certain gaps compared to other developed regions in terms of scientific research and education, especially in the production and sustainable development of yak husbandry. Till today, a local research and development system has not been developed.

There are 15 million yak in the world, of which 13.5 million are distributed in China. The TAR is the second province after the Qinghai Province in terms of yak population and has 30% of the total yak population. Such a large yak population is one of the main advantages for the TAR and the local Tibetans. This is the main source of meat, milk and butter. Although we have had only some success in yak research, development and technological extension, some of the achievements have reached a high level and has been successful in promoting the development of Tibetan livestock production and also improving the living condition of the Tibetan people. But we realise clearly that the advantages of yak production in the TAR has not yet been explored fully. Development and utilisation of yak resources are still relatively slow and lag behind. However, we think that there is great potential to develop yak production in the TAR.

To speed up the development of western China, the Central China Government has introduced the strategy to accelerate the development of western China at the turn of the century, which will play an important role in promoting economic development and social

stability. In this respect, we would like to take the opportunity to establish wider and closer co-operation in research and development (R&D) through reorientation of R&D so as to re-adjust the structure of agricultural production and thereby to promote economic development in the TAR.

The Third International Congress on Yak is a forum for the experts at home and abroad. It is a chance for all researchers and enterprisers to exchange experiences. It will also give us a lot of inspirations and directions. We will both learn from all experts and also hope that the friends from all over the world will invest in the TAR and discuss ways of co-operation that will help improve the economic development of the TAR. To achieve sustainable development of yak husbandry, let us join our hands to work together.

Finally, I wish you all a healthy and happy stay and a successful congress!

Thank you!

Chen Zhenrong
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Opening remarks, by Denis Hoffmann

Distinguished guests, participants, friends and especially our organising committee,

On behalf of the Director-General of the Food and Agricultural Organization of the United Nations (FAO), and the Assistant Director-General and Regional Representative for FAO in the Asia and Pacific Region, I wish you all a successful international congress. We, at FAO, recognise the significant contributions that the 15 million yak in the world make to the people of the mountainous regions of central Asia.

I am confident that this congress will promote the sharing of information and experiences in the hope to better identify constraints and solutions to problems associated with disease control, pastureland development and grazing, long-term breeding strategies, conservation of genetic resources, eco-tourism and product development in this region.

FAO has a focus on food security and poverty alleviation and play a co-ordinating role in fostering localised initiatives to overcome some of the problems that will be highlighted at this congress through dialogue and action. The ability of international agencies in general, including FAO, to get donor support for local and regional initiatives of the kind to be discussed at this congress will be dwindled. The clear message to all of us from the donor community is that they prefer individual country requests for assistance rather than the international agencies requesting the assistance. The donors do see a role for FAO to act as the regional co-ordinator or focal point of such activities. The preference is for regional organisation such as the Animal Production and Health Commission for Asia and the Pacific (APHCA), which is founded on the principle of technical co-operation between countries, to facilitate co-operation between multiple bilateral donor projects with national management.

I am certainly not an expert on yak, so I am here to listen and learn and help whenever possible.

Thank you!

Denis Hoffmann

Representative of FAO-Regional Office for Asia and the Pacific (FAO-ROAP),
Bangkok, Thailand

Opening remarks, by Horst E. Geilhausen

Respected honourable chairman, distinguished delegates, ladies and gentlemen,

As Acting President of the Yak and Camel Foundation (Krempe, Germany) I would like to thank the organisers of the Third International Congress on Yak, particularly the colleagues of the Tibetan Academy of Agricultural and Animal Sciences and Dr Han Jianlin, Head of the International Yak Information Centre (IYIC) at the Gansu Agricultural University (Lanzhou, P.R. China), that they were in the position to make it possible to have the congress here in Lhasa.

The Yak and Camel Foundation was founded in 1992 with the main objectives to scientifically document two species, namely the yak (*Bos grunniens*) and the two-humped camel (*Camelus bactrianus*). These animals enable human life under extreme climate conditions. The yak in the Himalayas in altitudes of 4000 to 6000 meters above the sea level and the bactrian camels in the deserts and desert steppes in Central Asia.

In line with its objectives, the Yak and Camel Foundation sponsors research and dissertation. As an example, on an annual basis awards for the three best yak publications are sponsored:

1. price = DM 2000
2. price = DM 1000
3. price = DM 500

Further activities encompass the realisation of scientific symposia. Thus the foundation co-organised and sponsored the First, the Second and the Third International Congresses on Yak in Lanzhou (Gansu, P.R. China) in 1994, Xining (Qinghai, P.R. China) in 1997, and Lhasa (Tibet, P.R. China) in 2000.

Thank you!

Horst E. Geilhausen
Yak and Camel Foundation, Krempe, Germany

Opening remarks, by J. Gabriel Campbell

Regional collaboration for applied yak research

Respected leaders of the Tibetan Autonomous Region, distinguished scientists and colleagues,

It is an honour for the International Centre for Integrated Mountain Development (ICIMOD), to join with our Chinese and international partners in supporting this important Third International Congress on Yak.

ICIMOD is dedicated to supporting integrated research and development in the Hindu Kush-Himalayan Region. Over 60 % of this region consists of rangelands, much of which is high altitude pastures between 2500 and 5000 meters above sea level.

The yak, as the only bovine to adapt to the cold and harsh conditions of this region has been instrumental in both nurturing and helping to shape its remarkable biodiversity, and patterns of landscape change in these mountain areas. The Tibetan Autonomous Region (TAR) is to be congratulated on establishing a nature preserve in the remote Chantang, which remains the last place where wild yak still survive.

The Hindu Kush-Himalaya is also the home of yak herders and farmers whose livelihoods and cultures have depended on the yak and its crossbreed progeny for millennia. The range of products and services provided by the yak is astounding, though not well understood outside the region, for example:

- wool and leather for clothing, shoes, blankets, bags, implements, rugs and tents;
- meat and milk for fresh food, dried food, and processed butter and cheese used for local consumption, sale and ceremonial offerings;
- transport for trade and agricultural production;
- financial assets and security for investments, accidents and family ceremonies; and
- manure for cooking, heating, and nutrient recycling.

The movement of yak through the diversity of herding regimes and trading patterns has also created and maintained economic and social networks, and contributed to regional stability and mutual understanding.

The future of the yak and the critical role it has played in the past is undergoing rapid change.

I understand from some of the zoologists and geneticists among us that there are important unanswered questions regarding the degree of genetic diversity, inbreeding and distribution of desired traits among yak—to name just a few that a non-biologist such as myself can comprehend. Survival of the species and livelihoods related to it will depend on the degree to which we continue to help yak adapt to our changing ecological and socio-economic environment and maintain its health.

Does this require more intensive breeding to develop increased productivity and disease resistance?

Does it mean we should co-operate more on the ground to exchange genetic resources across the region?

Do DNA tools allow us to collaborate internationally to improve the scientific basis for improved breeding?

I understand from some of the pasture, water and geography specialists among us that there are similarly important questions related to rangelands and forage.

Research throughout the world has documented how most traditional systems of range management maximised long-term sustainability by flexible community systems adapted to specific ecological situations. With roads and other extensive infrastructure development and agricultural intensification, the availability of rangelands, the amount of water they receive, and the species of plants in these pastures has changed. New policies have introduced fencing, on-farm forage production, and new forms of pasture management. All of these naturally disrupt previous systems, and there are important questions on their ecological, economic and social impacts.

Can we respect and make indigenous knowledge and range management a critical part of our scientific understanding of yak ecosystem management?

Can we use this understanding as the backbone of policies for assisting the wise yak herdsman and women to introduce positive change?

In addition, new market forces, a modern and global economy and aspirations for improved standards of living among the new generation of yak herders, also raise important questions for the future of yak-based livelihoods.

Surrounded by rangelands, yak and cattle, Lhasa, TAR, imports milk, butter and cheese from all over the world; trucks are the main transport for trade items throughout much of the region; hydroelectricity and kerosene power are used in cooking stoves; chemical fertiliser is replacing manure in cropping systems; cotton blue jeans, nylon bags and tents and polyester coats are replacing yak fabrics; the new generation wants to watch TV—and even the old one wants access to better health care for themselves and their animals.

As governments struggle to find means to address these changes, they often rely on familiar models developed from sedentary, plains-based systems. As my colleagues work in ICIMOD has shown, and I am sure some of your research also has addressed, these models are often not suited to the needs of yak herding and mountain peoples.

Can we improve milk, meat and fibre production, processing and marketing to increase incomes while retaining critical elements of traditional yak management?

Can we find ways to use new technologies, such as wireless communications and the Internet to bring distance learning, healthcare, and electronic commerce to overcome the barriers of moving populations?

Can we institutionalise participatory methods of planning and introducing change, including technological change, to increase local ownership and sustainability?

All these are not easy questions, and they require some of the rigorous and detailed scientific investigations that you are conducting and sharing with each other at this congress.

I congratulate you in this effort. As the world's leading experts in yak, the world policy makers rely on you to provide the research results and guidance upon which they can make wise decisions. I hope you can continue to build on the co-operation you are demonstrating today to improve and increase regional and international co-operation in yak research. I hope you can seek ways to communicate these results in simple and useable ways to yak herders, agricultural workers and policy makers.

I assure you that ICIMOD will continue to be a partner in these efforts. My colleagues, Camille Richard and Archana Karki, will be here throughout the week to participate in this congress and to share information on our work in the region.

With best wishes for a successful congress, and profound thanks to our hosts for bringing us together at this beautiful city on the roof of the world—the home of the magnificent, always slightly wild, and beautiful yak!

Thank you!

J. Gabriel Campbell
Director General, International Centre for Integrated Mountain Development (ICIMOD),
Kathmandu, Nepal

Brief introduction to agricultural and animal husbandry development in Tibetan Autonomous Region

Honourable chairman, distinguished delegates, ladies and gentlemen,

Today, the Third International Congress on Yak is being held here in Lhasa. As a yak researcher, I feel very happy and believe that this congress will help facilitate the speed of development of Tibetan yak husbandry. At this special moment, I would like to express my warmest greetings to all experts and scholars from home and abroad on behalf of the Department of Agriculture and Animal Husbandry of the Tibetan Autonomous Region (TAR), and all yak researchers in the TAR.

The TAR is an Autonomous Region of the People's Republic of China mainly inhabited by Tibetan people and comprising of 1.2 million km². It borders Xingjiang Province, Qinghai Province, Sichuan Province and Yunnan Province within China, and countries such as India, Nepal, Myanmar and Bhutan. The average elevation within the TAR is over 4000 metres above sea level (masl).

The TAR consists of 6 prefectures, 1 city and 75 counties with a total population of 2.5 million people.

The TAR is the highest and youngest plateau in the world with peculiar terrains and complicated climates. It has rich biological diversities and high elevation and low oxygen content. As far as the terrains are concerned, the TAR is surrounded by mountain ranges of Himalaya, Kunlun and Tanggula Mountains. The TAR is divided into four districts, that is Northern Tibetan plateau, Southern Tibetan valley, Eastern Tibetan canyon and Himalayan Mountain areas. Rivers, lakes and forests are found throughout the TAR. With regard to climate, the north-western part of the region is dry and cold while the south-eastern part is warm and humid with rich sunlight, strong radiation, low temperature, large differences in temperature, and a clear dry and humid season. The annual average temperature is from -5.6°C to -20°C, and rainfall decreases one hundred times from east to west (5000 to 50 mm/year). The average temperature of Lhasa is around 7.5°C, annual rainfall is about 444.6 mm, and the elevation is 3670 masl.

Animal husbandry is the basic industry of the TAR. Since democratic reform of the TAR, particularly since the adoption of open 'door policy' in China, animal husbandry and rural economy have progressed rapidly. There have been continuous good harvests for the last 12 years. The food production has increased by 79% since 1978 and the oil seed production has increased 4.1 times of that in 1978. The total agricultural production value has increased 11.3 times from that of 1978. The production value of rural industry and the per capita income has increased 77.4 times and 6 times, respectively, since 1978. At present, the goal to be self-sufficient in food that was set by the third planning meeting on development of the TAR by the Central China Government has been achieved. Food

supply problem for the majority of the local population has been solved. Some of the farmers are now even well off. There is now a balance in food supply and demand where there was a situation of food shortage in some regions. The agricultural development has entered into a new stage of development. The TAR is one of the five largest pastoral areas in China. Animal husbandry is essential to the livelihood of the local people and it is the fundamental backbone industry of the TAR. TAR has a total area of 65 million hectare of rangelands, of which 59 million hectare are usable rangelands. The total population of livestock is about 23 million. Tibetan animal husbandry has been following the policy that focuses on increasing the production, income and profitability. It is guided by the principle of 'controlling the number of animal, increasing off-take, bettering the structure of production, and improving the profitability of livestock development'. Based on the local condition and in accordance to the variation of livestock production systems, livestock production in the TAR will be categorically developed. It is clear that strengthening the pastoral production system and promoting crop–livestock interaction will speed up livestock development near urban areas. To do this, the following are needed:

- application of science and technology in livestock development
- reinforcement of infrastructure development
- promotion of commercialisation of livestock so that the livestock production system can be smoothly transformed from planned economy towards market economy, transformed from quantity oriented towards quality oriented production system, to eventually improve the productivity of livestock production system.

Yak is the domestic species that specially adapts to the Qinghai–Tibetan Plateau. It is tolerant to high altitude, cold conditions, and low quality feed and has high content of fat in milk, and good quality of meat and wool. Thus, in the TAR, it has been recognised as the most valuable animal in the high plateau. At present, there are more than 4 million yak in the TAR. For the last few decades, there has been great progress in developing yak husbandry. First, basic research on the ecology, biology and physiology of yak has been carried out and the productivity, eco–distribution, and characteristics of yak have been understood. Second, survey on the yak resources was conducted and the distribution of different breeds of yak in the TAR was fully understood. Third, the breeding program of yak has been strengthened so as to improve the productivity of yak. Fourth, the commercialisation of livestock production has been promoted so as to increase the economic profitability of livestock production.

With rapid development of the economy in the TAR, the agricultural and livestock development has been entered a new stage of development. Meanwhile, there is great opportunity for the TAR after the introduction of the policy of accelerating the development of western China. Further development of yak husbandry is one of the major priorities of readjusting and implementing the policy of accelerating the development of western China. Thus, utilisation and development of yak resources have to be strengthened and promoted. Our expectation is that yak husbandry will be a unique industry to the Qinghai–Tibetan Plateau and it might have a bright future in the near future. I am sincerely hoping that experts on yak from China and abroad will provide us with guidance and suggestion on yak production. I would like to express our warm welcome to all of you to invest in yak husbandry development in the TAR. Let us join our hands and contribute to

the development of yak production in the TAR so that it reaches a stage to challenge globalisation.

Finally, I wish a successful congress.

I wish all the delegates happy and healthy stay in Lhasa

Thank you!

Wang Wenpei

Deputy Director, Department of Agriculture and Animal Husbandry, TAR, P.R. China

Address on the opening dinner of the Third International Congress on Yak

Distinguished delegates, ladies and gentlemen,

I, on behalf of the People's Government of the Tibetan Autonomous Region (TAR), would like to take this opportunity to express our warmest welcome to the delegates of the Third International Congress on Yak.

We are very happy that the Third International Congress on Yak is being held in Lhasa. Being the main yak production area in China and also among other yak-raising countries, the TAR has a larger yak population. Yak is a very valuable resource of the TAR. Therefore, we should be at the position to contribute much more to the world in the field of yak research, development, and utilisation. I believe that this congress would be a good opportunity for us to learn and exchange experiences in yak research and development.

It is always a pleasure to greet a friend from afar. Experts whose major focus is on yak research and development from various parts of the world and sister provinces have gathered here in Lhasa, to explore yak research and development and to offer their excellences and ideas and to share the fruits of human civilisation. With the rapid development of science and technology, international co-operation and exchanges have become more and more important. This congress is not only a venue for scientific workshop, but should also serve as a venue for enhancing friendship. I am sure it can promote co-operation among countries and regions, while also strengthening research and development of yak husbandry.

September is the golden time in Lhasa with beautiful scenery. The hospitable Tibetan people in their own cultural manner welcome you to the sunshine city—Lhasa.

Finally, I would like to express our best wishes to all of you.

Cheers!

Gyalbu

Vice Governor, People's Government of the Tibetan Autonomous Region, P.R. China

Welcome speech to the Tibetan art performance

Ladies, gentlemen and friends,

In this golden harvest season, the Third International Congress on Yak is held in Lhasa. We are honoured to have both the domestic and foreign scholars and specialists come to Lhasa to participate in the congress.

On behalf of the Lhasa people, I am very happy to welcome all of you here and congratulate the opening of the Third International Congress on Yak.

Lhasa city has a history of 1300 years. It is the centre of politics, economy and culture in the Tibetan Autonomous Region (TAR). It also has beautiful scenery and plenty of sunlight. The weather here is quite mild—never too cold in winter and never too hot in summer. We also have many places of great interests. Potala Palace, as the major religious and historical building, with other temples located in Lhasa, form a special tourism site. At the same time, the unique blue sky, white clouds, grass fields and lakes enhance the great beauty of Lhasa. Lhasa always enjoys a good reputation all over the world. In recent years, travelling to Lhasa becomes a hot topic in both China and abroad. The number of tourists increases very rapidly. And the tourism business has developed greatly.

After the 13th CCIP, Lhasa, which is under the leadership of our party and government and with the help of all the other provinces and cities in China, enjoys a rapid progress in every respect. The infrastructure such as transportation, energy and communication is developing continuously. The construction held in Lhasa makes our city change day by day. Education, sanitation, literature and all the other social amenities develop rapidly. Commercial agriculture enjoys a great progress, which makes all our people live better. The further development of unique yak resources becomes really fast. The yak industry in the TAR is making its way to a bright future. I believe that from this congress we can promote our yak business in the TAR greatly.

At last, I am, on behalf of all the Lhasa people, again wish you a successful congress and a good time here. We truly hope all of you can have some time to appreciate our unique culture of Qinghai-Tibetan Plateau and enjoy the pleasure of the harvest with the Tibetan people.

Thank you!

Luosang Jiangcun
Mayor, Lhasa City, TAR, P.R. China

Closing remarks

Distinguished delegates, ladies and gentlemen, and friends,

With hard work and the commitment and co-operation of all the delegates, the Third International Congress on Yak is being closed today. The congress opened with a session on pastoral production systems followed by sessions on genetic diversity of yak, diseases and health care, nutrition and forage management, processing and marketing of yak products, reproduction and breeding, and environmental physiology of yak. During the congress, all delegates from China and abroad have exchanged and discussed latest achievements of research and key issues related to the development of yak husbandry. This will indeed play a very important role in learning and introducing experiences and knowledge for a sustainable development of yak production in Tibetan Autonomous Region (TAR).

From the very beginning of the preparations for this congress, we have got a lot of supports and assistances from various institutions and organisations from both the local government and abroad. As one of the main agencies related to yak research and development, the Tibetan Academy of Agricultural and Animal Sciences was assigned to organise the congress by the People's Government of the TAR. The Academy has thus prepared this congress as one of its major activities in this year. With great supports, co-operation and participations from all the delegates, this congress have been held very successfully. The aims of the congress, such as to learn from each other, to exchange information, to improve the understanding and to strengthen the collaboration, have been fully achieved. Today, on behalf of the People's Government of the TAR, let me express my sincere appreciation to all the organisations and delegates who have been supporting the congress.

In the present world, science and technology have been developing very rapidly, thus there is an increasing need for strengthening the exchange, sharing of information and working on environmental conservation. Yak is not only important for the TAR, but is also a very valuable resource for all human beings. Therefore, the utilisation of the yak resource should be targeted and research and development should be jointly conducted. The TAR is willing to keep long-term collaboration with all organisations mandated with research and development of yak. The TAR is also eager to adopt all new technologies and knowledge to contribute to mankind.

Distinguished guests, ladies and gentlemen, We have been very pleased to have the opportunity to organise the Third International Congress on Yak, which was held here in Lhasa, the ancient city on the Plateau. However, we also feel that there were limitations in our services during the congress. But we have sincerely offered our best. We really hope that we all join hands to strengthen the collaboration and widen research and development of yak husbandry so that the yak production will be further promoted.

I sincerely wish health and happiness to all the delegates.

Thank You!

Nyima Tsering

Vice Governor, People's Government of the Tibetan Autonomous Region, P.R. China