Food and Agriculture Organization
of the United Nations
Organisation des Nations Unies
pour l'alimentation et l'agriculture
Organización de las Naciones Unidas
para la Alimentación y la Agricultura

58
2016
ISSN 2078-6336

ANIMAL GENETIC RESOURCES

an international journal

RESSOURCES GÉNÉTIQUES ANIMALES

un journal international

RECURSOS GENÉTICOS ANIMALES

una revista internacional

2011-2020
United Nations Decade on Biodiversity

Editor-in-Chief
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Animal Genetic Resources is an international journal published under the auspices of the Animal Genetic Resources Branch of the Animal Production and Health Division, Food and Agriculture Organization of the United Nations (FAO).

Ressources génétiques animales est un journal international publié sous les auspices de la Sous-Division des ressources génétiques animales de la Division de la production et de la santé animales, Organisation des Nations Unies pour l'alimentation et l'agriculture (FAO).

Recursos genéticos animales es una revista internacional publicada bajo los auspicios de la Subdivisión de los Recursos Genéticos Animales de la División de Producción y Sanidad Animal, la Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO).

Print edition and institutional subscriptions / Édition imprimée et abonnements pour institutions / Edición de la impresión y suscripciones institucionales: Sales and Marketing Group, Office of Knowledge Exchange, Research and Extension, FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy; Fax: (39) 06 5705 3360; E-mail / courrier électronique / correo: Publications-Sales@fao.org or through FAO sales agents / ou auprès des agents de vente des publications de la FAO / o a través de los agentes de venta de la FAO.

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Edición en línea: Plataforma en línea de Cambridge University Press (www.journals.cambridge.org/agr). Por favor, visite la página inicial para acceder a la publicación, en la que pueden llevarse a cabo búsquedas textuales y se proporcionan enlaces a las referencias, y también para someter sus artículos electrónicamente. La versión electrónica está también disponible en la biblioteca del Sistema de Información sobre la diversidad de los animales domésticos, DAD-IS a www.fao.org/dad-is.

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RESSOURCES GÉNÉTIQUES ANIMALES

RECURSOS GENÉTICOS ANIMALES

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ORGANIZACIÓN DE LAS NACIONES UNIDAS PARA LA ALIMENTACIÓN Y LA AGRICULTURA

Animal Genetic Resources, 2016, 58, ii. © Food and Agriculture Organization of the United Nations, 2016
doi:10.1017/S2078633616000126

Editorial

Dear reader,

This issue features ten articles, with strong focus on ruminants. The majority of articles deal with characterization of breeds but also consider production environments. Improved understanding of the adaptedness of livestock breeds to production environments is indeed important for many decisions in the field of animal genetic resources management. As adaptedness is complex and difficult to measure, one approach to this problem is to characterize adaptedness indirectly by describing the production environments in which a breed has been kept over time, and to which it has probably become adapted. Enjoy reading!

We would also like to inform you that, while writing these lines the Animal Genetic Resources Branch of the Food and Agriculture Organization of the United Nations (FAO)[1] is busy with the preparation of the Ninth Session of the *Intergovernmental Technical Working Group on Animal Genetic Resources for Food and Agriculture* which will take place in Rome in July 2016. The Working Group was established in 1997 by the *Commission on Genetic Resources for Food and Agriculture*[2] to support its work in the animal genetic resources sector.

The Working Group will discuss topics such as

- Implementation and possible update of the *Global Plan of Action for Animal Genetic Resources*
- Review of the Funding Strategy for the Implementation of the Global Plan of Action for Animal Genetic Resources
- Access and benefit-sharing for animal genetic resources

Draft documents for the Session will be made available at the Working Group webpage[3] and you are warmly invited to have a look at them. You will find there the final version of *The Second Report on the State of the World's Animal Genetic Resources for Food and Agriculture*[4] as well as in-brief and brochure versions of the Second Report published in all official languages of FAO.

On the Working Group webpage you will also find information on the Global Databank for Animal Genetic Resources DAD-IS[5] which currently contains data from 182 countries and 38 species. Since 2014, the percentage of avian and mammalian breeds for which population data are available in DAD-IS has improved slightly, from 56 to 57 percent, and from 60 to 61 percent, respectively. The risk status remained essentially unchanged from 2014 to 2016; 17 percent of 8 822 breeds are currently classified as being at risk of extinction; 18 percent are classified as not at risk; 58 percent have unknown risk status and 7 percent are reported to be extinct.

The readership of *Animal Genetic Resources* might contribute to improve quantity and quality of data in DAD-IS. Therefore kindly have a look at the content of the Global Databank for Animal Genetic Resources of your country and, in case you have further data or research results, assist your National Coordinators for the Management of Animal Genetic Resources[6] in improving the content of DAD-IS.

Yours sincerely,

Roswitha Baumung

[1] http://www.fao.org/AG/AGAInfo/themes/en/AnGR.html
[2] http://www.fao.org/nr/cgrfa/en/
[3] http://www.fao.org/AG/AGAInfo/programmes/en/genetics/angrvent.html
[4] http://www.fao.org/3/a-i4787e.pdf
[5] http://www.fao.org/dad-is
[6] http://dad.fao.org/cgi-bin/EfabisWeb.cgi?sid=-1,contacts

Animal Genetic Resources, 2016, 58, iii. © Food and Agriculture Organization of the United Nations, 2016
doi:10.1017/S2078633616000138

Editorial

Cher lecteur,

Ce volume présente dix articles, se concentrant notamment sur les ruminants. La plupart des articles traitent de la caractérisation des races mais ils s'occupent également des environnements de production. Une meilleure compréhension de l'adaptabilité des races d'animaux d'élevage aux environnements de production est, en fait, importante pour la prise de décision dans le domaine de la gestion des ressources zoogénétiques. Vu que l'adaptabilité est complexe et difficile à mesurer, une approche à ce problème consiste à caractériser l'adaptabilité de façon indirecte, en décrivant l'environnement de production dans lequel une race a été maintenue au cours du temps et auquel elle s'est probablement adaptée. Bonne lecture!

Nous tenons aussi à vous informer qu'alors que nous écrivons ces lignes la Sous-division des Ressources Zoogénétiques de l'Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO)[1] se dépense pour préparer la Neuvième Session du *Groupe de Travail Technique Intergouvernemental sur les Ressources Zoogénétiques pour l'Alimentation et l'Agriculture*, qui se tiendra à Rome en juillet 2016. Le Groupe de Travail a été mis en place en 1997 par la *Commission des Ressources Génétiques pour l'Alimentation et l'Agriculture*[2] pour soutenir son travail dans le secteur des ressources zoogénétiques.

Le Groupe de Travail abordera des sujets tels que

- La mise en œuvre et la possible mise à jour du *Plan d'Action Mondial pour les Ressources Zoogénétiques*
- La révision de la Stratégie de Financement pour la Mise en Application du Plan d'Action Mondial pour les Ressources Zoogénétiques
- L'accès aux ressources zoogénétiques et le partage des avantages en découlant

Les ébauches des documents de la Session seront mises à votre disposition sur la page web[3] du Groupe de Travail et nous vous invitons cordialement à leur jeter un coup d'œil. Vous y trouverez la version finale du *Deuxième Rapport sur l'État des Ressources Zoogénétiques pour l'Alimentation et l'Agriculture dans le Monde*[4], ainsi qu'une version abrégée et une brochure du Deuxième Rapport dans toutes les langues officielles de la FAO.

Sur la page web du Groupe de Travail, vous trouverez également des informations sur la Banque de Données Mondiale pour les Ressources Zoogénétiques DAD-IS[5], qui contient actuellement des données de 182 pays et 38 espèces. Depuis 2014, le pourcentage de races aviaires et de mammifères pour lesquelles des données populationnelles sont disponibles a légèrement augmenté, de 56 à 57 pour cent et de 60 à 61 pour cent, respectivement. L'état de risque est resté quasiment le même de 2014 à 2016; 17 pour cent des 8822 races sont actuellement classées à risque d'extinction; 18 pour cent sont considérées comme n'étant pas à risque; pour 58 pour cent des races l'état de risque demeure inconnu et 7 pour cent des races sont signalées comme éteintes.

Les lecteurs de *Ressources Génétiques Animales* peuvent contribuer à améliorer la quantité et la qualité des informations contenues dans DAD-IS. Ainsi, nous vous prions de jeter un coup d'oeil au contenu de votre pays dans la Banque de Données Mondiale pour les Ressources Zoogénétiques et, au cas où vous auriez davantage d'informations ou des résultats de recherche, veuillez s'il vous plaît soutenir vos Coordonnateurs Nationaux pour la Gestion des Ressources Zoogénétiques[6] dans l'amélioration du contenu de DAD-IS.

Cordialement,

Roswitha Baumung

[1] http://www.fao.org/AG/AGAInfo/themes/fr/AnGR.html
[2] http://www.fao.org/nr/cgrfa/cgrfa-home/fr/
[3] http://www.fao.org/AG/AGAInfo/programmes/fr/genetics/angrvent.html
[4] http://www.fao.org/3/a-i4787e.pdf
[5] http://www.fao.org/dad-is
[6] http://dad.fao.org/cgi-bin/EfabisWeb.cgi?sid=3d3aace15f7f4bfe48397b41108a3159,contacts

Animal Genetic Resources, 2016, 58, iv.
doi:10.1017/S207863361600014X

Editorial

Estimado lector,

Este volumen presenta diez artículos, con el acento especialmente puesto en los rumiantes. La mayoría de los artículos tratan sobre la caracterización de las razas pero también hacen alusión a los entornos de producción. Una mejor comprensión de la capacidad de adaptación de las razas de ganado a los entornos productivos es, de hecho, importante para la toma de decisiones en el ámbito de la gestión de los recursos zoogenéticos. Dado que resulta complejo y difícil medir la capacidad de adaptación, una aproximación a este problema consiste en caracterizar la capacidad de adaptación de manera indirecta, es decir mediante la descripción del entorno de producción en el que una raza ha sido mantenida a lo largo del tiempo y al cual probablemente se ha adaptado. ¡Disfrute de la lectura!

Querríamos también hacerle saber que, mientras escribimos estas líneas, la Subdivisión de los Recursos Zoogenéticos de la Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO)[1] se emplea a fondo en la preparación de la Novena Reunión del *Grupo de Trabajo Técnico Intergubernamental sobre los Recursos Zoogenéticos para la Alimentación y la Agricultura*, que tendrá lugar en Roma en julio de 2016. El Grupo de Trabajo fue constituido en 1997 por la *Comisión de Recursos Genéticos para la Alimentación y la Agricultura*[2] para apoyar su labor en el campo de los recursos zoogenéticos.

El Grupo de Trabajo abordará temas tales como

- La implementación y la posible actualización del *Plan de Acción Mundial sobre los Recursos Zoogenéticos*
- La revisión de la Estrategia de Financiación para la Aplicación del Plan de Acción Mundial sobre los Recursos Zoogenéticos
- El acceso a los recursos zoogenéticos y el reparto de los beneficios que resultan de su utilización

Los borradores de los documentos de la Reunión se van a poner a su disposición en la página web[3] del Grupo de Trabajo y le invitamos cordialmente a darles un vistazo. Encontrará ahí la versión final del *Segundo Informe sobre la Situación de los Recursos Zoogenéticos Mundiales para la Alimentación y la Agricultura*[4], así como una versión resumida y un folleto del Segundo Informe en todas las lenguas oficiales de la FAO.

En la página web del Grupo de Trabajo, hallará asimismo información sobre el Banco de Datos Mundial para los Recursos Zoogenéticos DAD-IS[5], que contiene actualmente información de 182 países y 38 especies. Desde 2014, el porcentaje de razas de aves y mamíferos para las cuales se dispone de censos en DAS-IS ha aumentado ligeramente, del 56 al 57 por ciento y del 60 al 61 por ciento, respectivamente. El estado de riesgo permaneció prácticamente inalterado de 2014 a 2016; el 17 por ciento de las 8.822 razas están actualmente clasificadas como en peligro de extinción; el 18 por ciento están clasificadas como no en peligro; para el 58 por ciento se desconoce su estado de riesgo y el 7 por ciento restante se tiene ya por extinguido.

Los lectores de *Recursos Genéticos Animales* pueden contribuir a mejorar la cantidad y la calidad de los datos recogidos en DAD-IS. Así, les rogamos que echen un vistazo al contenido de su país en el Banco de Datos Mundial para los Recursos Zoogenéticos y, en caso de que posean mayor información o resultados de investigación, apoyen por favor a sus Coordinadores Nacionales para la Gestión de los Recursos Zoogenéticos[6] en la mejora de los contenidos de DAD-IS.

Atentamente,

Roswitha Baumung

[1] http://www.fao.org/AG/AGAInfo/themes/es/AnGR.html
[2] http://www.fao.org/nr/cgrfa/cgrfa-home/es/
[3] http://www.fao.org/AG/AGAInfo/programmes/es/genetics/angrvent.html
[4] http://www.fao.org/3/a-i4787e.pdf
[5] http://www.fao.org/dad-is
[6] http://dad.fao.org/cgi-bin/EfabisWeb.cgi?sid=3d3aace15f7f4b-fe48397b41108a3159,contacts

Animal Genetic Resources, 2016, 58, 1–12. © Food and Agriculture Organization of the United Nations, 2015
doi:10.1017/S2078633615000326

Indigenous cattle breeds and factors enhancing their variation, potential challenges of intensification and threats to genetic diversity in Uganda

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Summary
Indigenous cattle support approximately 26.1 percent of Ugandan families through provision of food and income in addition to the supply of socio-cultural wealth and security. Cattle keepers have developed and maintained variations of indigenous cattle phenotypes and genotypes suited to their agro-ecological zones through traditional management practices and socio-cultural aspects. The Ankole (*Bos taurus indicus*), East African shorthorn Zebu (*Bos indicus*) and their crossbred cattle constitute the main indigenous breeds, adding up to 93.3 percent of the Ugandan herd. With intensions to increase productivity, state policies encourage livestock farmers to upgrade local genotypes towards high yielding exotic dairy cattle. This if not appropriately planned is likely to result into loss of local genetic diversity, well endowed with resilience to local climatic conditions, endemic diseases and feed resource constraints. Here in, we review literature related to indigenous cattle in Uganda including how diverse landscapes, local management practices and socio-cultural aspects have enriched patterns of indigenous cattle variations. Then we highlight potential challenges of intensive management, increased selection for higher productivity and threats to genetic diversity of indigenous cattle populations. Since indigenous cattle vary with landscapes and socio-cultural values, have taken decades to establish, efforts to save them through genetic diversity studies, conservation and farmers sensitization should be undertaken immediately.

Keywords: *Agro-pastoral and pastoral, Ankole, East African shorthorn zebu, genetic variation, intensification, Uganda*

Résumé
Les bovins indigènes se soutiennent environ 26.1% des familles ougandaises par la fourniture de nourriture et de revenus, en plus de la fourniture de la richesse et de la sécurité socio-culturelle. Les éleveurs de bovins ont développé et maintenu variations de phénotypes et les génotypes de bovins indigènes adaptées à leurs zones agro-écologiques (ZAE) grâce à des pratiques de gestion traditionnelles et les aspects socio – culturels. Le Ankole (Bos taurus indicus), shorthorn Afrique de l'Est Zébu (EASZ) (Bos indicus) et leurs hybrides constituent les principales races de bovins indigènes, en ajoutant jusqu'à 93.3% du troupeau ougandaise. Avec intensions pour augmenter la productivité, les politiques de l'Etat encouragent les éleveurs à améliorer génotypes locaux vers les bovins élevés laitiers exotiques rendement. Cette si pas prévu de manière appropriée est susceptible d'entraîner dans la perte de la diversité génétique locale, bien dotée en la résilience aux conditions climatiques locales, les maladies endémiques et les contraintes de ressources d'alimentation. Ici, dans, nous passons en revue la littérature liée aux bovins indigènes en Ouganda, y compris la façon dont divers paysages, pratiques de gestion locales et les aspects socio- culturels ont renforcé types de variations de bovins indigènes. Ensuite, nous mettons en évidence les défis potentiels de la gestion intensive, une sélection accrue pour une meilleure productivité et des menaces à la diversité génétique des populations de bovins indigènes. Depuis les bovins indigènes varient avec des paysages et des valeurs socio-culturelles, ont pris des décennies à établir, les efforts pour les sauver à travers des études de la diversité génétique, la conservation et la sensibilisation des agriculteurs doivent être prises immédiatement.

Mots-clés: *Ankole, la variation génétique, gardiens de bovins indigènes, agro-pastorale et pastorale, Zébu shorthorn Afrique de l'Est, Ouganda*

Resumen
El ganado bovino autóctono sostiene a, aproximadamente, el 26.1 por ciento de las familias ugandesas mediante el abastecimiento en alimentos y el aporte de ingresos, además de por su importancia sociocultural en términos de riqueza y seguridad. Los criadores de ganado bovino autóctono han desarrollado y mantenido variaciones en el fenotipo y en el genotipo del ganado, que se adecúan a sus zonas agroecológicas, por medio de las prácticas tradicionales de manejo y por influencia de aspectos socioculturales. El ganado Ankole (*Bos taurus indicus*), el Cebú de Cuernos Cortos del Este de África (EASZ por sus siglas en inglés, *Bos indicus*) y sus cruces

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constituyen las principales razas autóctonas, llegando a representar hasta el 93.3 por ciento de la cabaña ugandesa. Con la intención de incrementar la productividad, las políticas estatales animan a los ganaderos a mejorar los genotipos locales con la vista puesta en el ganado lechero exótico de alta producción. Esto, si no se planifica adecuadamente, puede fácilmente llevar a una pérdida de la diversidad genética local, bien dotada de resistencia a las condiciones climáticas locales, a las enfermedades endémicas y a las limitaciones en la alimentación. En este artículo, revisamos la documentación existente sobre el ganado bovino autóctono de Uganda, incluido cómo diferentes entornos, prácticas locales de manejo y aspectos socioculturales han generado patrones de variación en el ganado bovino autóctono. A continuación, hacemos hincapié en los desafíos que pueden derivar del manejo intensivo, de una mayor selección para incrementar la productividad y de las amenazas a la diversidad genética de las poblaciones bovinas autóctonas. Dado que han sido necesarias décadas para que surgieran en el ganado bovino autóctono las variaciones debidas al entorno y a los valores socioculturales, los esfuerzos necesarios para preservarlas deben iniciarse cuanto antes (estudios de diversidad genética, proyectos de conservación y la sensibilización de los ganaderos).

Palabras clave: *Ankole, agropastoral y pastoral, Cebú de Cuernos Cortos del Este de África, variación genética, intensificación, Uganda*

Submitted 13 June 2015; accepted 22 September 2015

Background

At least 26.1 percent of Uganda's rural households derive their livelihoods from indigenous cattle (MAAIF *et al*., 2010) which constitutes 93.3 percent of the national herd. However, 1.2 million rural households from cattle keeping areas in Uganda have been reported to experience food insecurity (IRIN, 2013). Globally, a rapid human population growth rate, increased urbanization and escalating consumer preferences occurring in most parts of the developing world is a serious threat to food security (Thornton, 2010). Food insecurity is more evident among the rural poor households who are mainly engaged in smallholder crop-livestock farming systems (Delgado *et al*., 1999; Delgado, 2003). Smallholder farming systems have been perceived as less likely to satisfy the demand for foods of animal origin set to dramatically increase (MAAIF, 2013). In order to arrest this situation, a High Level Panel of Experts on Food Security and Nutrition (HLPE, 2013) has argued that increased capitalization of smallholder livestock enterprise systems could provide a dependable conduit out of poverty and food insecurity for nearly one billion people in sub-Saharan Africa. Since about 26.1 percent of the Uganda's households derive most of their livelihood from indigenous cattle (MAAIF *et al*., 2010), government and local non-government organizations (NGOs) perceive increased capitalization of smallholder livestock farming systems as a springboard for poverty reduction (Baltenweck *et al*., 2007). As a result current national livestock policies encourage smallholder livestock farmers to cross-breed their indigenous cattle towards the more specialized high yielding exotic breeds in a bid to increase productivity (Taberlet *et al*., 2008). This is being done without conservation plans of the indigenous genetic resources which manifests as variation of the indigenous cattle adapted to the different landscapes (Taberlet *et al*., 2008). Indigenous cattle are well endowed with adaptive traits to endemic diseases, fragile climatic conditions and poor feed resources (Hanotte, Dessie and Kemp, 2010; Hoffmann, 2010) and the current cross-breeding practices may result into an irreversible loss of genetic variation (Taberlet *et al*., 2008). Indeed, scientists have already warned that this loss spells disaster for Africa's food security and livestock genetic pool for the next generation (Seré *et al*., 2008; Hanotte, Dessie and Kemp, 2010). Before more losses are realized, there is a need to study in a landscape approach the current genetic variation among the indigenous breeds and how geographic and socio-cultural factors have influenced these patterns of variations (Joost *et al*., 2007; Pariset *et al*., 2009; Schwartz *et al*., 2009). In this study we review literature concerning indigenous cattle in Uganda with the aim of establishing how management factors, socio-cultural values and landscapes influence variations among local indigenous cattle genotypes. Finally we have highlighted the consequences of intensive management systems, selection for increased productivity traits and the threats to indigenous cattle diversity in Uganda.

Review methodology

A search of peer-reviewed studies on indigenous cattle breed diversity was conducted from comprehensive databases including Google Scholar, PubMed, Science Direct, Swetswise and CAB direct. The search was extended to available theses, conference proceedings, project reports etc. The search was restricted to English language articles. Keywords were standardized across the databases to produce comparable searches and these were: Ankole; genetic variation; indigenous cattle keepers; agro-pastoral and pastoral; East African shorthorn zebu; Uganda. References of all relevant articles were also searched to identify articles that could have been missed in the search. A total of 430 records were retrieved. All records were imported in to Microsoft Excel, and articles

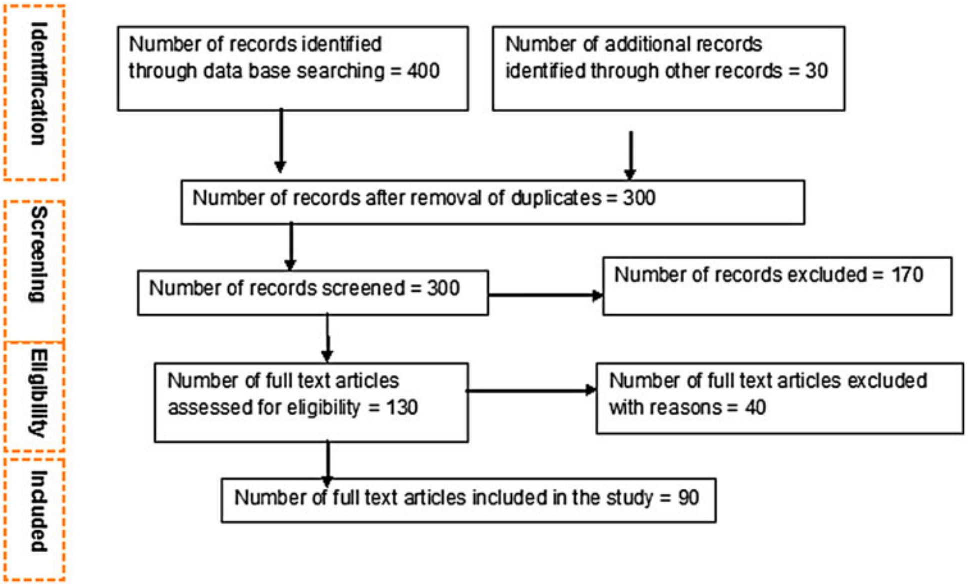

Figure 1. A flow chart of the methodology used to identify and review literature on Indigenous cattle breeds and factors enhancing their variation, potential challenges of intensification and threats to genetic diversity in Uganda (Adopted from PRISMA flow diagram (Moher et al. 2009).

presenting duplicate titles/findings were removed to obtain 300 records. Further screening was done by title and abstract focusing on studies reporting on indigenous cattle breeds and factors enhancing their variation, potential challenges of intensification and threats to genetic diversity in Uganda and countries with similar situations yielding 130 text articles published as of May 2015. Additional screening of the articles then identified the most relevant ones for Uganda yielding 90 articles which were used in this review. Figure 1 shows a flow chart of the methodology used to identify and review literature used in this report (Moher *et al.*, 2009).

Indigenous cattle breeds in Uganda

Uganda has a total of 10.64 million indigenous cattle, representing 93.3 percent of the national herd of 11.4 million (MAAIF/UBOS, 2010). The Ankole and East African shorthorn Zebu (EASZ) constitute the main traditional cattle breeds in Uganda. Other breeds are variants and intermediates of the two including Nganda, Nkedi, Kyoga, Nyoro and Kigezi (Rege and Tawah, 1999). Although indigenous cattle have been faulted for low productivity and reproductive performances, they still remain popular in Uganda because of their adaptive traits to the local underprivileged conditions (Balikowa, 2011). Below is a brief description of the indigenous cattle breeds.

The Ankole cattle

The Ankole cattle have been naturalized in Uganda having been imported from North-eastern Africa about 600 years ago (Rege, 1999) by the Hamitic (Bantu) pastoralists. In addition to Uganda, Ankole cattle are found in Burundi, Democratic Republic of Congo (DRC), northern Tanzania and Rwanda. In Uganda, the Ankole cattle are mainly present in the western and south-western rangelands but also some parts of central Uganda (Okello and Sabiti, 2006; Ndumu *et al.*, 2008).They are part of the Sanga linage of cattle which probably evolved in Ethiopia as a product of interbreeding between the original longhorn non-humped cattle with the cervico-thoracic humped zebu cattle (Rege and Tawah, 1999; Rege, 1999; Kugonza *et al.*, 2012). Having evolved within Africa, the Ankole cattle constitute an indispensible Animal Genetic Resource (AnGR). They are reared by the pastoral and agro-pastoral farming communities in a typical subsistence traditional farming system, thus constituting an indispensable and unique AnGR well adapted to the local tropical conditions. They are characterized by a medium to large body frame with a small cervico-thoracic hump, large, long and curved white horns. The coat colour is mainly red, fawn, brown and often spotted with white. Several ecotypes have emerged as a result of different indigenous cattle keeping communities who benefit a supply of food and income for recurrent needs, risk aversion, accumulation of cultural wealth and prestige (Wurzinger *et al.*, 2006).

The EASZ cattle

The EASZ cattle (*Bos indicus*) were introduced into the East African region by the Arab traders through the East African coast from Western Asia (Payne, 1990; Rege, 1999). Several variations of Shorthorn Zebu cattle are reared in the eastern and southern Africa, all commonly referred to as the “East African Zebu”. However, based on their sizes and conformation, two main populations of Shorthorn Zebu are recognized and these are “the large” and "small" groups (Rege, 1999). The large Zebu types traditionally inhabit the marginal lands of northern Kenya, north-eastern Uganda, southern Sudan, southern Ethiopia and western Somalia. The small East African Zebu cattle have a smaller and more compact body as compared with the large Zebu. They are more common in the much wetter habitats and manifest greater variations in size and conformation. However, both the small and large Zebu types are believed to be of common lineage. Mwacharo *et al.* (2006) have attributed the variations in size to have resulted from adaptive response to the prevailing natural environment.

Variation among cattle populations, its origins and importance

Only two cattle domestication centres, the Fertile Crescent at the border of Iran, Iraq and Turkey, and the Indus valley of today's Pakistan (Bradley *et al.*, 1996; Freeman *et al.*, 2006) have been fully documented. The progenitor of modern cattle is the extinct wild auroch (*Bos primigenius*) (Ajmone-Marsan, Garcia and Lenstra, 2010) which lived as two subspecies in the Fertile Crescent and the Indus Valley which have given rise to a vast variation present in cattle populations today. Enormous variations arose after subsequent dispersal of cattle over different continents and adaptation to various environments (Ajmone-Marsan, Garcia and Lenstra, 2010).

This wide variety of characteristics evolved more or less naturally over a few thousands of years, but has recently been rapid leading to the development of well defined, specialized and genetically isolated breeds (Ajmone-Marsan, Garcia and Lenstra, 2010). Cattle variations based on geographical, ecological or cultural isolations with heritable characteristics such as colour markings, unique morphologies and differences in yields have resulted into the modern distinct breeds (FAO, 2003, 2007). Felius *et al.* (2014) have noted that the natural distribution of *B. taurus* and *indicus* is successfully restricted to regions with similar climatic conditions to those of the earlier domestication centres in the Fertile Crescent and the Indus Valley, respectively.

Wilson (2009) has described fitness traits of tropical indigenous livestock that may equally apply to cattle which give them comparative advantage to survive in the tropics better than the temperate breeds. They are: – a lower metabolic rate that produces less heat; reduced panting but more ready sweating that preserves energy; a feed intake which is less affected by high ambient temperatures; a higher ability to survive on lower quality feed; higher digestibility and efficiency of feed conversion; lower water requirement; a greater ability to retain feed and water in the large intestine and better resistance to ticks, insects and some diseases. Indeed these qualities are present among indigenous cattle populations of Uganda with different variations.

Today, several breeds have emerged as a result of interbreeding related indicine and taurine cattle. This tends to occur in localities without distinct boundaries as is the case of Ankole-Zebu crosses giving rise to unique variations of the two such as the Nganda and Nyoro cattle in central Uganda. Variation has not emerged to be studied at a later time as a basis for classification of cattle, genetic diversity and adaptation. Studying the factors which enhance indigenous cattle variation in contrasting landscapes could provide a baseline for landscape genomic research and conservation approaches thus establishing the gene pool for next generation livestock farming.

Traditional management systems and their influence on indigenous cattle variation

Traditional management systems by either opening grazing and/or tethering on communal pastures are the mainstay of traditional cattle management practices in East Africa (Muhereza and Ossiya, 2004). These systems form a continuum between agro-pastoralism and pastoralism in Uganda (Nalule, 2010; Balikowa, 2011). Livestock farming communities select breeding sires and dams with specific traits to enhance resilience to the challenges of pastoralism and agro-pastoralism in their localities. This selective breeding enhances cattle population adaptive traits to extremes of either system with tendencies to develop variations (Franktin and Mearns, 2003). For example, in the semi-arid region of north eastern Uganda, the climatic conditions vary from arid to semi-arid with seasonal availability of pasture and water (Loquang and Köehler-Rollefson, 2005; Nalule, 2010), to which traditional Karamojong shorthorn zebu cattle are well adapted. Similar although less severe conditions apply to the Bahima pastoral communities in the South-western pastoral rangelands of Uganda (Kugonza *et al.*, 2012). Indigenous cattle provide the most suitable means of exploiting marginal lands with scarce resources and sustainable pastoral livelihoods (Hoffmann, 2011). The farmers' selection criteria of breeding cattle under this system would opt for resilience traits observed in parent stock associated with strong well-developed musculature to enable long distance movement in search for pastures and water (FAO, 2007). While in the agro-pastoral areas of the Lake Victoria Crescent agro-ecological zone (AEZ) where cattle are mainly tethered, selection will target docile cattle to enable frequent handling. Such selection is likely to result into locally adapted variations of indigenous cattle. Presently, local farmers' choices greatly influence patterns of genetic variation which has not yet been fully studied, similar to the morphometric variation lately documented (Kabi *et al.*, 2015).

The role of socio-cultural practices in indigenous cattle variations

Cattle keeping communities in Uganda have deliberately bred cattle as a socio-cultural prestige in addition to being a primary source of livelihood to households (Kugonza *et al*., 2011). Several indigenous breeds are connected to a specific ethnic group or community, which is often reflected in the breed names such as the Nganda and Ankole cattle (Kohler-Rollefson, 2003; Krätli, 2008). Different cattle keeping communities deliberately breed cattle to develop favoured unique variations (FAO, 2007, 2009). This practice has been observed among the Ankole cattle communities where unique morphological features such as the shape of horns and colour markings (Ndumu *et al*., 2008; Kugonza *et al*., 2012) create a sense of ownership while meeting the traditional desires of the communities. Some of these practices were initiated by the pre-colonial monarchies for gifts and presents to beloved ones or ceremonies and festivities (Ndumu *et al*., 2008). As a result cattle populations in Uganda have been named according to tribal communities such as the Teso zebu for the Itesot speaking community and Nyoro cattle for the Banyoro speaking communities. This accounts for great variation among indigenous cattle populations within the country.

The traditional cattle keepers from the West Nile region, North-eastern and South-eastern Uganda keep the EASZ cattle. The specific features of the EASZ cattle such as size and shape of horns, multiple colourations, body size are carefully selected for by kraal leader through utilization of specific sires and dams (Loquang and Köehler-Rollefson, 2005; Nalule, 2010). These too account for significant variations among cattle populations. The Karamojong Zebu cattle, Nkedi Zebu, Lango Zebu and the Nganda Zebu are the common varieties belonging to the various cattle keeping communities in Uganda.

The role of landscape features to variations among indigenous cattle populations

Uganda is endowed with unique physical features such lakes, rivers, highlands and rift valleys. These features provide exclusion barriers within geographical and ecological locations dividing indigenous cattle inhabitants into several subpopulations. Breeding of cattle within the same localities have definitely concentrated specific features (productivity, resilience and adaptive) which vary from one locality to another as could be influenced by the landscape as previously described by Grimaud *et al*. (2007). Pastoral communities select breeding cattle with attributes to withstand challenges created by landscapes, this is common in semi-arid region of Karamoja where cattle have to trek long distances in search of pastures and water (FAO, 2007; Nalule, 2010). In the South-western rangeland cattle will utilize pastures on the higher altitudes during the wet seasons and are moved to the lower altitude valleys in the dry seasons. This requires adaptation to seasonal movements between the different altitudes. This local adaptation could potentially create significant variations between the cattle in the rangelands, plateaus and highlands.

The role of adaptation to endemic diseases

Cattle keeping communities in rural areas may not have access to adequate modern disease control and veterinary services. For example, Gradé, Tabuti and Van Damme (2009) note that cattle present in the semi-arid regions do not access adequate veterinary services. In such situations cattle get adapted to seasonal movement away from areas with high disease risks created by insect vectors emergence during the rainy seasons and will return when the dry season sets in. However, minimal continuous exposure to specific diseases such as East coast fever will result into exhibition of non-clinical disease conditions loosely related to endemic stability within a population as lately described (Kabi *et al*., 2014). Such practices will result into indigenous cattle genotypes yet to be described that vary with different disease challenges and control practices (Carval and Ferrier, 2010). Several studies have indicated that indigenous cattle can endure and be sustainably productive in the presence of disease challenges, a phenomenon referred to as tolerance or resilience to disease (Baker and Gray, 2004; Bishop, 2012) and endemic stability (Jonsson *et al*., 2012) to infection. In pastoral areas of Uganda, the humid climatic conditions favour proliferation of vectors creating an endemic disease presence (Otim *et al*., 2004; Ocaido *et al*., 2005; Moloo, Kutuza and Borehan, 2006). The continuous exposure of endemic diseases such as tick borne diseases among indigenous cattle populations has led to the development of tick borne disease tolerant traits (Jonsson *et al*., 2012). However, these unique traits (such as endemic stability among indigenous cattle) may be lost due to stringent tick control measures being imposed on indigenous cattle in order to protect exotic naïve breeds imported in Uganda since the former are regarded as source of infection (Okello-Onen *et al*., 1998). Disease outbreaks among populations with low genetic variation have been reported to result into high morbidity and mortality rates as is the case with exotic genotypes compared with genetically diverse livestock populations (Mirkena *et al*., 2010; Danchin-Burge *et al*., 2012).

Based on the above factors of variation, an appropriate cattle population would require most of these traits, such as adaptation to local physical landscape, nutritional and management environments; acceptability to local communities' socio-cultural needs; resistance to the endemic diseases of the area; good reproductive and growth performance; and adequate yields of meat, milk, draught power related to the prevailing management system. Similar qualities have also been alluded to by Wilson (2009). However, it is worth noting that adaptive traits may not be positively correlated to increased productivity as shown by unfavourable genetic correlation between milk yield and the incidence of ketosis, ovarian cyst, mastitis and lameness. This means that continued selection for higher milk yield will increase incidence rates for these production diseases and reduce the well-being of dairy cows (Ingvartsen, Dewhurst and Friggens, 2003).

Generally, the critical factor for increased productivity in farm animals is the availability of insufficient resources for adequately coping with environmental stresses and disease pathogen challenges (Rauw, 2009). This indirectly assigns limits to further increase in productivity of livestock in the tropics where endemic disease challenges are quite high.

The potential challenges of intensification of smallholder livestock farming systems

Increasing quality of farm inputs and services

Improvement of rural household incomes is part of Uganda's obligations to the Millennium Development Goals initiatives (MAAIF *et al.*, 2010). In view of the circumstances that most of the rural households derive much of their livelihoods from smallholder livestock farming systems. Policy makers and other stakeholders envisage the commercialization of livestock production as one of the favourable option, both to meet the increasing demand for livestock products in addition to contributing to poverty reduction among households (Otte and Upton, 2005; MAAIF *et al.*, 2010; Udo *et al.*, 2011). This policy and practice will most likely lead to intensive cattle management systems. However, intensification demands increased use of purchased high quality inputs and services, such as feed supplements, replacement stock, breeding and veterinary health services (Bebe *et al.*, 2003; Otte and Upton, 2005; Udo *et al.*, 2011). This means that in practical terms more investment will be needed and it is the affluent livestock farmers who may have the capacity to benefit from the increased demands for livestock products. This paints a dark cloud over the benefits of intensification of smallholder livestock farming systems especially among the majority of the rural poor. Cooperatives for bulk milk marketing and purchase of inputs, and modern management skills will be needed urgently. This calls for revitalization of farmers' credit and cooperative saving schemes which were abolished during privatization of public enterprises in Uganda to assist small scale farmers with procurement of farm inputs, value addition and marketing of milk and its products.

Intensified selection of cattle

After livestock were domesticated, selection criteria mostly targeted phenotypic behavioural traits such as calmness in cattle for non-problematic handling and beautiful colour patterns (Oltenacu and Broom, 2010; Taberlet *et al.*, 2011) in addition to productivity traits to provide better livelihoods among households. However, in the last 40 to 60 years, interest has mainly shifted to genetic improvement of productivity traits, including milk yield and beef in cattle (Oltenacu and Broom, 2010). Consequently milk productivity has tremendously increased in various farming systems within the tropics over the recent decades as observed by Galukande *et al.* (2013). However, this has to be accompanied with intensive management practices, without which the maintenance of increased productivity remains quite challenging to rural smallholder livestock farmers. In other regions, high productivity has been accompanied by challenges such as reduced capacity to reproduce, increased incidence of metabolic disorders and declining longevity in modern dairy cows (Van Raden, 2004; Oltenacu and Algers, 2005). Lameness is a common welfare challenge for dairy cows in the UK (Webster, 2000; Amory *et al.*, 2008) which is usually complicated by loss of weight, poor feed intake, lowered milk production and higher risks of reduced fertility, mastitis and eventually culling (Weaver, 2000). The incidence of metabolic disorders and production ailments tends to occur whenever high yielding cows are unable to satisfy the high metabolic requirements of maintenance, pregnancy and lactation (Rauw *et al.*, 1998). For example severe forms of hypocalcaemia or hypomagnesaemia occur when the cows run short of calcium and magnesium in circulation, respectively (Rauw *et al.*, 1998). Other diseases such as ketosis and fat liver syndrome occur due to above normal energy demands (Webster, 2000). Without specialized veterinary attention and manufactured nutritional farm inputs, huge losses will usually result. Intense selection for high milk yield has also been linked to high infertility levels (Webster, 2000). Increased milk yield is genetically correlated to longer calving intervals, more days to first service and lowered chances of conception at first service. The resultant infertility is the main reason for culling in dairy cows (Whitaker, Kelly and Smith, 2000). Nørgaard, Lind and Agger (1999) conclude that a higher level of physiological stress due to higher milk yield and concentrate consumption has led to increased mortality in dairy cows. Intensified selection for increased productivity without fitness is now being discouraged in developed countries due to welfare reasons (Oltenacu and Broom, 2010).

Selective breeding for increased productivity in tropical countries like Uganda must be accompanied with agro-ecological fitness to counter metabolic, unsustainable feed resources and endemic diseases challenges as suggested by Eisler *et al.* (2014). Intensive selective breeding for increased productivity in Uganda can be successful if well planned to counter the negative effects which usually occur at extremely high levels of productivity of cross-bred cattle. In India for example the Sunandini synthetic cattle breed has been developed through a well-organized crossbreeding programme between the Jersey, Brown Swiss and Friesian and the local cows of Kerala state, with the involvement of local farmers' interests resulting into high milk production (Chacko, 2005). The Australian Friesian Sahiwal is another popular synthetic breed with 50:50 Sahiwal:Friesian developed and maintained by the Queensland government in Australia for more than 30 years before being privatized. Among other traits, this breed is known to have good tick resistance, milk yield traits and well adapted to tropical grazing pastures (Stephens, 2006).

Threats to indigenous cattle diversity in Uganda

In general, several authors have accepted the fact that AnGR is on the decline due to several factors acting as threats to the latter (Eisler *et al.*, 2014). For example Bett *et al.* (2013) have noted that the Ankole and Nganda cattle genotypes have become gradually threatened due to cross-breeding with exotic dairy breeds. Likewise the Nkedi and Lugbara zebu linage could be disappearing due to breed substitution with Ankole and Karamajong, respectively. The Kigezi breed could be threatened due to the high human population pressure in its homeland of south western highlands, increased cross-breeding with the more productive exotic genotypes and suitable environmental conditions (Bett *et al.*, 2013).

The use of exotic germplasm, changes in production systems, because of socio-economic factors, natural disasters (drought, famine, disease epidemics, civil strife/war) and exploitation of rangeland resources have been cited as the major causes of genetic erosion (Rege and Gibson, 2003; Gibson *et al.*, 2006; Taberlet *et al.*, 2008) however, these are common in the rest of the world but also occur in Uganda.

Changes in producer preference due to socio-economic and policy factors

The increasing demand for foods of animal origin and improvement in income levels have tempted livestock farmers and policy makers towards the utilization of specialized high yielding breeds (Delgado, 2003). In Uganda, smallholder cattle farmers have been encouraged to replace their indigenous cattle with high yielding exotic breeds (Grimaud *et al.*, 2007; Balikowa, 2011). This is a widespread consequence of the need to increase productivity, although it is latently accompanied with narrowing of within-breed genetic variation (Kantanen *et al.*, 2015). This is a big threat to indigenous cattle genetic diversity among agro-pastoral and pastoral farmers. Regions where this practice was previously promoted have reported loss of genetic variation (Kantanen *et al.*, 2015). In Europe for example, 200 breeds of indigenous cattle have been replaced only by 20. This is undesirable in the current uncertain times of climate change.

Introduction of exotic germplasm

Use of exotic germplasm has been the approach in the desire to increase productivity in the tropics. Several initiative such as cattle zero-grazing and semi-intensive cattle farming with increased upgrading towards the more productive exotic cattle have been popularized in tropics including Uganda (Galukande *et al.*, 2013). The use of artificial insemination, embryo transfer and exotic village bull schemes have been used at various stages as tools to support the introduction of exotic germplasm especially in cattle since 1960 (Galukande *et al.*, 2013). In Uganda, these practices have been mainly amplified by local NGOs and other developmental community based organizations targeting smallholder cattle farmers with the objective of increasing milk productivity (Balikowa, 2011). Unfair competition from vigorously promoted commercial European breeds (Rege and Gibson, 2003) even where such genotypes are inappropriate (King *et al.*, 2006; Hanotte, Dessie and Kemp, 2010) have been observed. No comprehensive national breeding program has been established to produce cattle that would easily get adapted to the local disease conditions, usually resulting into high mortality rates among improved dairy cattle (Bebe *et al.*, 2003; Bayemi *et al.*, 2005; Galukande *et al.*, 2013). Despite the successes associated with cross-breeding, the practice has faced challenges such as limitations of skilled techniques (inadequate heat detection), mismatches between genotypes and production system where environmental conditions cause stress affecting heat detection, intermittent funding of programmes, lack of appropriate supportive policies and limited involvement of farmers in the design of the interventions. Unplanned use of exotic germplasm will most likely lead to loss of the much cherished indigenous cattle traits including endemic disease tolerance, adaptation to poor quality pasture and high environmental temperatures (Taberlet *et al.*, 2008). Improved dairy cattle are more vulnerable to local diseases and parasites particularly tick-borne diseases, internal helminths and trypanosomosis (Magona, Walubengo and Kabi, 2011), whose effective control requires substantial investments.

Changes in production systems

Indigenous cattle are managed by open grazing on communal rangelands, involving mobility in search of pastures and water in resource-scarce and highly variable marginal areas to enable human habitation and subsistence (Krätli *et al.*, 2013). This is implemented in the form of sophisticated herd movements and grazing strategies to save forage for critical periods for sustainable utilization. However, successive colonial and post-independence government policies have always advocated for the settlement of pastoralists to enhance governance and political control (Inselman, 2003; AU-IBAR, 2012) faulting pastoralism as backwards and wasteful. In certain circumstances, increased population growth has *in addition* limited the availability of land available for pastoral nomadic movement, forcing pastoralists to *revert to* settled agriculture (Grimaud *et al.*, 2007). The above have resulted into reduced mobility of pastoralists and their livestock, but may hasten loss of indigenous AnGR since local farmers are further enticed to indiscriminately cross-breed their cattle.

Breakdown of traditional and cultural leadership as a consequence of disaster

Livestock keeping communities have for long established traditional and cultural leadership institutions in order to ensure long-standing sustainable pasture management, water supply and AnGR (Rathore and Kohler-Rollefson, 2002; Homann, Dalle and Rischkowsky, 2004; Nalule, 2010). Due to continued conflicts and civil wars, community leaders are not able to enforce these leadership roles which would enable them to sustainably utilize scarce natural resources in the region (Nalule, 2010; Stites, Fries and Akabwai, 2011; AU-IBAR, 2012). The council of Jie and Dodoth ethnic elders of Karamoja region have previously planned for the sustainable use of grazing pastures and water for livestock. Lack of comprehensive livestock management system due to the breakdown of traditional leadership as a continuous civil strife has resulted into degradation of rangeland resources which supplies livestock feeds thus threatening AnGR (Nalule, 2010).

Exploitation of natural resources within pastoral areas

Exploitation of oil and minerals in the Albertine region of Western savannah grassland zone and the Northeastern Drylands zone, respectively, will definitely interfere with the natural ecosystem of wildlife and plants (Kityo, 2011). Indigenous cattle which benefit from this ecosystem will lose access to feed and water resources. This is a threat to AnGR in the region.

Discussion and conclusion

Variations of indigenous cattle populations have augmented their agro-ecological fitness in Uganda while supporting several cattle keeping communities through provision of household livelihoods. This paper reviewed literature to establish how traditional management factors, contrasting landscapes and socio-cultural practices have influenced indigenous cattle variations. Additionally, challenges associated with intensive management initiatives, increased selection for higher productivity and associated threats to indigenous cattle diversity were elucidated.

From the review of available literature, indigenous cattle breeds including the Ankole and EASZ in Uganda have been regionally structured until recently when cattle trade and restocking plans have led to widespread dispersal of the two main breeds. Several indigenous cattle intermediate populations of the Ankole and EASZ occur patronized by other cattle keeping communities (Balikowa, 2011; Kabi *et al*., 2015). The Ankole have been naturalized in the southwestern and western regions, while the EASZ have been mainly reared in the eastern, northern and west Nile regions. This breed distribution structure could be attributed to points of entry and settlements of immigrant cattle keepers and promotion by the pre-colonial traditional leadership in Uganda (Hanotte *et al*., 2000). Ankole cattle that are present in Uganda, DRC, Rwanda, Burundi and western Tanzania could have arisen from livestock movements that followed Bantu immigration from the Niger-Cameroon region, along the Atlantic coast, or through the rainforest basin into the African Great Lakes region (Hanotte *et al*., 2000). While the EASZ cattle that are believed to have moved inland following their introduction at the east African coast by Arab traders. The Zebu cattle spread was further enhanced by local pastoral communities and their natural resistance to the Rinderpest epidemic of the late nineteenth century (Epstein, 1971). Traditional management practices (selective breeding and grazing patterns), different landscapes, socio-cultural needs and endemic disease challenges have overtime enhanced indigenous cattle breed adaptation to their localities. The adaptations to diverse AEZs take the form of variations in body sizes and levels of productivity (Kugonza *et al*., 2011), morphometric traits variations (Kabi *et al*., 2015) and resilience to endemic diseases (Magona, Walubengo and Kabi, 2011; Kabi *et al*., 2014). Currently, intensive cattle management policies are being popularized for increased productivity and prospective poverty alleviation (MAAIF, 2013). Developing countries mostly rely on cross-breeding towards the industrial livestock genotypes as a standard approach to the improvement of livestock production more especially for dairy cattle productivity. Several authors allude to the fact that at a higher level of cross-bred cattle, local animal genetic resources are lost (Thomas *et al*., 2002; Udo *et al*., 2011; Galukande *et al*., 2013). Thus the call for national conservation plans of indigenous livestock resources to act as a source for future generation livestock farming. Additionally, several case-studies by Bebe *et al*. (2003) and Udo *et al*. (2011), reported that intensification demands increased use of purchased inputs and services, including feeds, replacement stock, breeding and veterinary health services, credit facilities, producer organizations and market access for both inputs and outputs, and an increase in livestock management skills.

Udo *et al*. (2011), further noted that the less financially privileged farm households may exhibit less interest in investing their scarce resources and efforts in more intensive livestock systems. The socio-cultural and capital asset roles will remain important for these households. Furthermore, without robust development policies that deliberately consider the opportunities and threats likely to be met by mixed crop-livestock farming systems, these households are likely to miss out from the increased market opportunities for livestock intensification initiatives. Commercial industrial breeds of interest must only be promoted with adequate guidance in suitable ecologies and under appropriate management, while retaining the adaptive traits among indigenous cattle breeds. It is also worthy understanding that the modern breeding techniques such as artificial insemination, embryo transfer, cryopreservation and cloning from which industrial breeds are benefitted for wide popularization may also contribute immensely to the conservation and promotion of local breeds.

Awareness of the value of indigenous cattle genetic variations has now attracted lots of attention and can no longer be overlooked with respect to the different landscapes of Uganda. Indigenous cattle breeds adapted to contrasting landscapes and ecosystems need to be conserved since they constitute an important genetic source for next generation farming. Conservation efforts should be well planned to enable maintenance of within breed and between breed variations with consideration of their agro-ecological habitats. Within-breed variation is critical for the genetic adaptation of a population to changes in the production and economic environment and for averting inbreeding problems. With regard to the increasing demand of foods of animal origin, stakeholder must create policies that will enable the poor to obtain a share in the expanding market for livestock products. The policies include introduction of savings and credit schemes, removal of market barriers to trade in traditional livestock products and improvement of social services to rural farming communities.

Acknowledgements

We thank the Next generation methods to preserve farm animal biodiversity (NEXTGEN) project and the Eastern Africa Agricultural Productivity Project (EAAPP) for providing the logistics for this study.

Statement of interest

The authors have no conflict of interest to declare.

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Animal Genetic Resources, 2016, 58, 13–29. © Food and Agriculture Organization of the United Nations, 2016
doi:10.1017/S2078633616000035

Phenotypic characterization, population structure, breeding management and recommend breeding strategy for Fogera cattle (*Bos indicus*) in Northwestern Amhara, Ethiopia

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Summary
The study was carried out in selected districts in the Northwestern Amhara, from October 2012 to May 2013. The objective of the study were to undertake on-farm and on-station phenotypic characterization of Fogera Cattle in comparison with two different local cattle population, to characterize the population structure and to identifying trait preferences, breeding management and to recommend breeding strategy for Fogera cattle. Both purposive and random samplings were employed. Data were gathered through semi-structured questionnaire, focus group discussions, field observations, census data, direct count and body measurements. About 126 smallholder farmers were interviewed. About 21 quantitative and 17 qualitative phenotypic data types were also generated from 332 cattle. The Effective population size (Ne) and rate of inbreeding (ΔF) were calculated from the counted population structure data. Both GLM procedures of SAS and descriptive statistics of SPSS software's were employed for data analyses. The results indicated that Fogera cattle were kept mostly for milk (97.62 percent). The main threats identified for the survival of Fogera cattle were scarcity of feed resources and interbreeding with other indigenous cattle, which are less demanding in terms of feed. Fogera cattle population has specific morphological appearance. Generally about 65.2 percent of male pure-Fogera cattle population are having large hump and large dewlap (93.5 percent) with cervico-thoracic (82.6 percent) hump position and long tail (97.8 percent), respectively. The coat pattern of male pure-Fogera cattle is dominated by the spotted coat pattern (82.6 percent) with 43.5 percent white black and 39.1 percent black white coat colour. Female Fogera cattle have medium (94.4 percent) hump size at cervico-thoracic positions (73.2 percent), large dewlap (62.7 percent) and long tail which is well below the hock (91.5 percent). The coat pattern of female pure-Fogera cattle is dominated by white spotted (80.3 percent) with 43.0 percent white black and 33.1 percent black white coat colour Most of the quantitative traits were highly significantly ($P \leq 0.001$) affected by breed type. Except horn length and horn space all of quantitative traits for both sexes of pure-Fogera cattle from on-station were significantly ($P \leq 0.05$) larger than those of the on-farm. The average linear body measurement taken on a total of 46 male pure-Fogera cattle populations were 42.68 ± 0.56 cm (mouth circumference), 16.35 ± 0.72 cm (horn length), 37.04 ± 1.16 cm (dewlap width) and 129.17 ± 1.33 cm (height at wither). The average linear body measurements for female pure-Fogera cattle were 38.23 ± 0.18 cm (mouth circumference), 13.81 ± 0.37 cm (horn length), 27.20 ± 0.42 cm (dewlap width) and 123.68 ± 0.52 cm (height at wither). The population structure were dominated by Pure-Fogera constituting 37.02 percent, Interbred with Fogera (33.71 percent) and non-Fogera (29.23 percent). The effective population size of pure-Fogera cattle was 4295, with 9016 total population. The average inbreeding level for the population was 0.012 percent. Inbreeding is at a low level and the effective population size is large. The calculated parameters indicate satisfactory genetic diversity in Fogera cattle. Milk yield, colour, power, body size and growth rate of Fogera were the most dominant traits perceived to be good by the respondents. The special qualification of this breed is to live at high amount of flooding areas with adapting other very challenging environment. Pure breeding of pure-Fogera, interbred with Fogera and non-Fogera type of breeds was used for breeding practice with natural mating. The Andassa Research Center established in 1964 as Fogera cattle population improving centre, but according to different source, population viability and population structure indicated that the population are not viable and highly admixture with other indigenous cattle breeds. According to this in order to improve the population status of Fogera cattle we recommended control with open-nucleus breeding strategy. So in order to minimize the risk status of this breed and conserve for the future generation any responsible agent should be given priority.

Keywords: *breeding strategy, characterization, Fogera cattle, inbreeding, quantitative traits*

Résumé
L'accroissement individuel des coefficients de consanguinité (ΔF_i) a été recommandé comme une mesure alternative de la consanguinité du fait qu'il tient compte des différences dans la connaissance que l'on a de la généalogie des animaux individuels et vu qu'il évite la surestimation résultant d'un plus grand nombre de générations connues. L'effet de la consanguinité (F) et de la consanguinité équivalente (EF), celles-ci calculées à partir de ΔF_i, sur les paramètres de croissance a été étudié dans des troupeaux de moutons Nilagiri et Sandyno. L'étude s'est basée sur des données conservées à la Station de Recherche pour l'Amélioration des

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Ovins (Sandynallah). La généalogie était moins connue et le nombre équivalent de générations était plus faible pour les moutons Sandyno que pour les moutons Nilagiri. Les valeurs moyennes de F et de EF pour la population Nilagiri ont été respectivement de 2,17 et 2,44, avec les valeurs correspondantes pour les moutons Sandyno ayant été respectivement de 0,83 et 0,84. Dans les deux populations, l'évolution suivie au cours des années par la consanguinité montre que EF était plus élevée dans les premières générations, pour lesquelles moins d'information sur la généalogie était disponible. Parmi les effets significatifs de la consanguinité, la dépression de la croissance a varié de 0,04 kg pour le poids au sevrage à 0,10 kg pour le poids à un an de vie pour chaque 1 pour cent d'augmentation de la consanguinité. En général, les caractères affectés par la consanguinité ont été plus nombreux chez les moutons Nilagiri, pour lesquels une plus forte dépression des paramètres de croissance avec F qu'avec EF a été observée. L'obtention de valeurs plus élevées pour EF que pour F dans les premières générations des deux populations révèle que EF a évité la possible surestimation du coefficient de consanguinité dans les générations récentes. La dépression de la croissance par l'effet significatif de la consanguinité a été plus forte dans la population Sandyno. Les différences décelées dans les deux populations pour ce qui est de la réponse à F et à EF et les causes possibles de ces différences sont dûment discutées.

Mots-clés: *moutons, consanguinité, accroissement individuel de la consanguinité, dépression, croissance*

Resumen

El incremento individual de los coeficientes de endogamia (ΔF_i) ha sido recomendado como una medida alternativa de la endogamia ya que tiene en cuenta las diferencias en el conocimiento que se tiene de la genealogía de animales individuales y evita la sobreestimación debida a un mayor número de generaciones conocidas. El efecto de la endogamia (F) y de la endogamia equivalente (EF), calculadas a partir de ΔF_i, sobre los parámetros de crecimiento fue estudiado en rebaños de ovejas Nilagiri y Sandyno. El estudio se basó en datos conservados en la Estación de Investigación para la Mejora del Ganado Ovino (Sandynallah). Se dispuso de menos información sobre la genealogía y el número equivalente de generaciones fue menor para las ovejas Sandyno que para las ovejas Nilagiri. Los valores medios de F y EF para la población Nilagiri fueron de 2,17 y 2,44, respectivamente, y los valores correspondientes para las ovejas Sandyno fueron de 0,83 y 0,84, respectivamente. En ambas poblaciones, la evolución seguida a lo largo de los años por la endogamia hizo ver que EF era mayor en las generaciones tempranas, en las que la información sobre la genealogía fue escasa. Entre los efectos significativos de la endogamia, la depresión del crecimiento varió de 0,04 kg en el peso al destete a 0,10 kg en el peso al año de vida por cada 1 por ciento de incremento de la endogamia. En general, fueron más los caracteres que se vieron afectados por la endogamia en las ovejas Nilagiri, en las cuales se observó una mayor depresión de los parámetros de crecimiento con F que con EF. La detección de mayores valores para EF que para F en generaciones tempranas de ambas poblaciones indica que EF evitó la posible sobreestimación del coeficiente de endogamia en generaciones recientes. La depresión detectada en parámetros de crecimiento por un efecto significativo de la endogamia fue mayor en la población Sandyno. Se discuten debidamente las diferencias advertidas en las dos poblaciones en la respuesta a F y EF y las posibles causas de estas diferencias.

Palabras clave: *ovejas, endogamia, incremento individual de la endogamia, depresión, crecimiento*

Submitted 13 June 2015; accepted 12 February 2016

Introduction

Domestic animal diversity is an important component of global biodiversity. About 40 species of domestic animals and poultry contribute to meeting the needs of humankind. Within these species, more than 8 000 breeds and strains constitute the animal genetic resources (AnGR) that are of crucial significance for food and agriculture (FAO, 2011a).

The loss of diversity in domestic species has important economic, ecological and scientific implications as well as social considerations (Shah, Patel and Bhong, 2012). Information on both within- and between-breed diversity is important, as the former provides information for management at the breed level and the latter helps to identify divergent breeds that may harbour distinct genotypes and are therefore worthy of conservation efforts even if their within-breed diversity is relatively high (Shah, Patel and Bhong, 2012). Understanding the diversity, distribution, basic characteristics, comparative performance and the current status of a country's animal genetics resources is essential for their efficient and sustainable use, development and conservation (FAO, 2007). In the recent past, effective breeding has emphasized on a few specialized stocks (Simianer, Marti and Gibson, 2003); however, breeds that have been less studied have been at risk of population decline because of neglect of their genetic potential, lack of protection of their genetic diversity and uncontrolled crossing (Barker, 2002; Mao, Chang and Yang, 2006).

Approximately 70 percent of the world's rural poor depend on livestock as an important component of their livelihoods (Hoffmann, 2010). Cattle breeds account 897 and 154 in the world and in Africa, respectively. The African continent is home to over 230 million cattle. These breeds have unique genetic attributes such as adaptation and tolerance to drought, heat, diseases and ability to utilize low-quality indigenous forages (FAO, 2007).

Ethiopia is home to large indigenous cattle populations with diverse breeds, ecotypes and characteristics (Rege, 1999; Rege and Tawah, 1999; Workneh, Ephrem and Markos, 2004). The country ranks sixth in the World and first in Africa in its cattle population (AGP, 2013). The cattle population estimated at 55.03 million are well adapted to the tropical environment producing and reproducing under stresses of high degree of temperature, high disease prevalence and low level of nutritional status (CSA, 2014). Of the total cattle population found in the country, 99.4 percent are indigenous types and about 42 percent are milk cows owned and managed by smallholder farmers and pastoralists (Institute of Biodiversity Conservation, 2004; Workneh, Ephrem and Markos, 2004 and Rowlands, Nieves and Hanotte, 2006).

The Fogera cattle is among the 27 recognized indigenous cattle breeds in Ethiopia and it is found distributed around Lake Tana in south Gonder and west Gojjam zone of Northwestern Amhara. There are no clear data confirming their utility, they are called triple use; drought, milk and meat (Addisu, Mengistie and Adebabay, 2010). The population of Fogera cattle was estimated to be around 800 000 in 1980s (Alberro and Haile-Mariam, 1982), 636 000 heads in 1998 (Institute of Biodiversity Conservation, 2004) 86 800 heads in the 1999s (Rege, 1999) and 15 000 heads in 2000s (Gebeyehu, Azage and Tezera, 2003). There was no recent, clear, complete and objective data confirming their phenotypic character of this breed on-farm and on-station, population structure, breeding management and breeding strategy. Therefore, this study was initiated with the aim of undertake on-farm and on-station phenotypic character of Fogera cattle in comparison with other two cattle populations, to evaluate the population structure and to identify trait preferences, breeding management and to recommend breeding strategy for Fogera cattle in the selected districts of Northwestern Amhara, Ethiopia.

Materials and methods

Description of the study area

The research was conducted in the selected districts of North Gonder, South Gonder and West Gojjam zones of the Northwestern Amhara (Figure 1). Description of the study sites is presented in Table 1.

Sampling technique

Both purposive (for Districts, PAs, Villages/*Gotes* and interviewers) and random (for herds) sampling techniques were used. First each study districts were selected purposely based on their potential of Fogera cattle. After selection of districts discussions were held with the livestock experts of the rural and agricultural development office of each district to know the specific areas (peasant associations (Pas)) of current concentration of pure-Fogera breed. Based on the outcome of the discussions, a total of nine PAs or three PAs in each district were purposively selected based on the population of Fogera cattle. After selection of each PAs additional discussions were held at the PAs level with selected older or aged farmers, PAs livestock experts and PAs

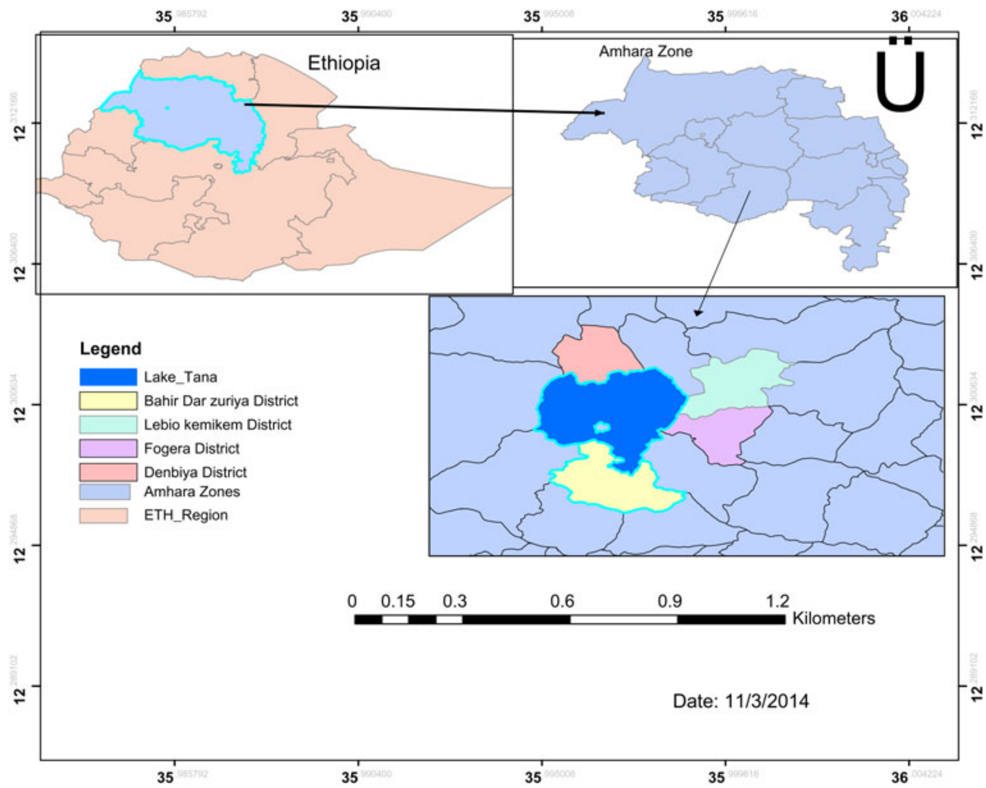

Figure 1. Map of study districts.

Table 1. Description of the study sites.

On-farm districts

Characteristics	**Districts**		
	Dembia	**Libo kemkem**	**Fogera**
Zone	N/Gonder	S/Gonder	S/Gonder
Area (h)	148 968	108 157	117 414
Altitude (m)	1750–2100	1 800–3 000	1774–2410
Number of PAs	42	34	30
Administrative centre	Kola Diba	Addis Zemen	Woreta
Distance from Addis Ababa	771	645	625
Distance from Bahir Dar	210	79	55 km
Annual rainfall (mm)	700–1160	1233.7	1103–1336
Temperature ranges (°C)	18–28	19–30	10.3– 27.2
Total human population	27 102	198 433	231 086
Livestock population	559 935	499 794	617 680
Cattle	314 423	115 452	182 729

On-station (Andassa Livestock Research Center)

Zone	District	Established	Location	Altitude	Distance AA	Distance Bahir Dar	Rainfall	Temperature	Area	Cattle population
w/Gojjam	Bahir Dar Zuria	1964	11°29′N and 37°29′E	1 730	587	17	1434	13.1–27.9	300	471

representatives to know the specific Villages/*Gotes* of historical place or habitat and high concentration of Fogera cattle population and hence 27 Villages or *Gotes*/three Villages or *Gotes* in each PA were selected considering the breed historical place or habitat and concentration. In each selected Village, five Fogera cattle owners and three herds were selected for interviewing and morphological measurement, respectively.

Method of data collection

Phenotypic characterization

Data were collected by researcher through the designed and pretested semi-structured questionnaires from 126 selected households at purposive selected villages. In each of the selected PA, one focus group discussion was held with few selected (5–8 individuals per group) pure-Fogera cattle owners. Points for discussions were origin and history of the breed, their typical features, cattle breeding practices, concentration of the breed, current status of the breed and broad prospects and constraints on Fogera cattle breed. In each selected Villages/*Gotes*, five Fogera cattle owners were purposely selected for administration of semi-structured questionnaire. From each selected Villages/*Gotes* one herd with 158 average populations was selected for linear body measurements and phenotypic characterization of pure-Fogera cattle, interbred with-Fogera and non-Fogera cattle. The Andasa Research Center Fogera breed populations were used as a pure-Fogera breed type. Linear body measurements and body weight were taken using a standard measuring tape. The three types of breeds were identified using special characteristic of Fogera cattle breed (Rege and Tawah, 1999). Accordingly, the following total samples were used for the study (Table 2).

A total of 17 qualitative and 21 quantitative traits were considered. The sample populations were scored early in the morning, having had no access to feed or water. The weight of the animals was estimated from heart-girth measurement. Perception of cattle owners and dentition were used to determine the age of the animals in the three on-farm districts and in the Andassa Research Center besides the measurement, the record of birthing date of each animals used and calculate the current age. The questionnaires were designed based on the information check lists developed by FAO (2012). Both the qualitative and quantitative traits collected were adapted from the standard breed descriptor list developed by FAO (2012). Both qualitative and quantitative variables were recorded in pre-coded format.

Population structure

In each randomly selected herds (admixture of pure-Fogera, interbred with Fogera and non-Fogera cattle population) in purposive selected villages (expected Fogera cattle population found villages), Peasant Association and Districts the population structure was counted by classifying by breed (Fogera, interbred with Fogera and non-Fogera), sex (male and female) and age (oxen (>4 years and castrated), cow (>4 years and have one and above calve), bull (>2 years and uncastrated), heifer (>2 years and have not calve before) and calves (male and female (0–2 years)).

Methods of estimation of genetic diversity

Effective population sizes per study site and per total population was estimated following Caballero (1994); Berger and Cunningham (1995); Falconer and Mackay (1996); Hedrick (2000); Frankham, Ballou and Briscoe (2004) as

$$N_e = \frac{4N_m \times N_f}{N_m + N_f},$$

where, $N_e =$ the effective population size, $N_m =$ the number of breeding males, and $N_f =$ the number of breeding females.

The rate of inbreeding (ΔF) for each home range and for the total population will be estimated using the Ne estimated in equation below and by the model suggested by Falconer (1989); Nomura (1996); Hedrick and Kalinowski (2000); Nomura, Honda and Mukai (2001); Frankham, Ballou and Briscoe (2004) and Maiwashe,

Table 2. Sample of phenotypic characterization.

Districts/Research Center	No PAs	No villages	No questionnaires	No group discussion	Morphological characterization								
					Male				Female				Total
					Breed type				Breed type				
					PF	IF	NF	Total	PF	IF	NF	Total	
Dembia	3	9	36	3	12	9	9	30	30	15	15	60	90
Libo	3	9	45	3	12	9	9	30	30	15	15	60	90
Fogera	3	9	45	3	12	9	9	30	30	15	15	60	90
Andasa	–	–	–	–	10	–	–	10	52	–	–	52	62
Total	9	27	126	9	46	27	27	100	142	45	45	232	**332**

PF, pure-Fogera breed; IF, interbred with- Fogera; NF, non-Fogera breeds.

Nephawe and Van der Westhuizen (2006) as:

$$\Delta F = \frac{1}{2}N_e.$$

The expected inbreeding coefficients (IC) and retained heterozygosity (RH) both for will be predicted starting from the exiting population by using the population estimated in equation above and by models following Frankham, Ballou and Briscoe (2004) as IC at:-

$$F_1 = \frac{1}{2}N_e,$$

$$F_2 = \frac{1}{2}N_e + \left(1 - \frac{1}{2}N_e\right) * \frac{1}{2} = 1 - \left(1 - \frac{1}{2}N_e\right)^2.$$

Therefore IC at F_t will be estimated as

$$F_t = 1 - \left[1 - \left(\frac{1}{2}N_e\right)\right]^t.$$

Retained/expected heterozygosities at F_t were estimated as

$$RH_t = \left(1 - \left(\frac{1}{2}N_e\right)\right)^t.$$

where $F_1 =$ the filial generation for observed inbreeding rates, $F_t =$ the expected inbreeding rates IC = the inbreeding coefficients, $\mathrm{RH}_t =$ the retained/observed heterozygosity for RH_1, $\mathrm{RH}_2 =$ for the expected heterozygosity and $t =$ the generation time (8).

Trait preference and breeding management

Data were collected by researcher through the designed and pretested semi-structured questioners from 126 randomly selected households. Points for questioners were breed preferences, purposes of keeping Fogera cattle, trait preference and special or desirable qualities of Fogera breed, adaptability trait/tolerance levels of Fogera breed, breeding practice, mating system, source of breeding bulls and purpose of keeping them, culling method, heat detection methods and signs of heat, consideration during selecting breeding animals and major breeding problems in the study areas. The data collected from the field through questioners were entered into IBM SPSS statistics 20 was employed to analyse the data. Indices were calculated for ranked variables.

Recommend breeding strategy

Based on the result of trends of the current breeding practice, population structure and population viability analysis the future breeding strategy for Fogera breed was recommended.

Data management and analysis

The data collected from the field through questionnaire and linear body measurements and secondary sources were entered into computer using Excel software. SAS 9.0 (1999) and IBM SPSS statistics 20 (2011) was employed to analyse the data. The SPSS 20 program was used to describe the questioner data. Indices were calculated for ranked variables.

The quantitative and qualitative data were analysed for sexes (male and female), breed types (pure-Fogera, interbred with Fogera and non-Fogera) and districts (Dembia, Libo Kemkem, Fogera and Bahir Dar Zuria/Andassa Research Center) separately as fixed effects. General Linear Model (GLM) procedure of multivariate analyses of SAS (1999) for quantitative traits and SPSS 20 analysis for qualitative traits were used for data to differentiate between districts, breed and sex. Simple descriptive statistics and frequency procedure was used to compile the observed categorical traits and chi-square test was employed to test independence of the categorical variables. To quantify the effect of independent variables (district, breed type and sex) on the linear body measurement (dependent variables) of the sample populations, the GLM procedure of SAS (1999) was employed.

The model fitted for analysis of data on the linear body measurements for both sample populations was

$$Y_{ijkl} = \mu + B_i + D_j + S_k + e_{ijkl},$$

where Y_{ijkl} is the measurement on the lth animal of ith breed type ($i =$ pure-Fogera, cross-Fogera or non-Fogera) from jth district ($j =$ Dembia, Libo Kemkem, Fogera or Bahir Dar Zuria/Andassa Research Center) and kth sex ($k =$ male or female) for estimated body weight and linear body measurements;

$\mu =$ Overall mean or the general mean common to all animals considered in the study; $B_i =$ Fixed effect of the ith breed type (pure-Fogera, interbred with-Fogera and non-Fogera); $D_j =$ Fixed effect of the jth districts (Dembia, Libo, Fogera and Bahir Dar Zuria or on-farm and on-station); $VSk =$ Fixed effect of the lth sex of the sample population (male and sex); $e_{ijkl} =$ Residual random effects peculiar to each animal.

Results and discussion

Phenotypic characterization

Origin, distribution and typical features of the pure-Fogera breed

According to the focus discussion and key informants the pure-Fogera breed type is found in some specific villages and monasteries around Lake Tana Districts (Fogera, Libo Kemkem and Dembia). This study also confirmed that pure-Fogera breed is found specific villages and monasteries around Lake Tana Districts (Fogera, Libo Kem kem and Dembia) (Table 3.).

Black and white coat colour is the most features of the pure-Fogera breed was reported and saw. The colours are

Table 3. The distribution and population of pure-Fogera cattle.

Districts	Peasant associations	Specific villages	Population size
Dembia	Averjia	Mandaba Monastery, Bergeda Mariam Monastery and Kes Mender	801
	Deber Zuria	Muza, Robet and Kossen	572
	Tana Weyena	Mamuye, Lekelek one and Lekelek two	337
Libo Kemkem	Kave	Bahir Mender, Kokor Mender and Lameye	1290
	Aged Keregna	SheMender, Fota and Abay Merecho	474
	Tezanba	Fota two, Daga and Aroye Beret	864
Fogera	Navega	Sarko, Fogera Bet and Kubaza	1515
	Kideste Hana	Dengize, Hode Gebia and Gerare	1113
	Wagetera	Weshet, Zorfa and Tache Amesa	1649
Bahir Dar Zuria	Andassa	Andassa Research center	471

more white and black (more white with some black) (43.24 percent), black and white (more black with some white) (36.12 percent), white (8.9 percent) and red white (7.89 percent) and also in some cases black (2.49 percent). Physically the breed are large because of this most of their body parts are relatively larger than other indigenous cattle types. Their dewlap is large (78.09 percent), long tail (94.65 percent), large udder (45.8 percent), medium teat size (62.7percent) and large scrotal size (45.65 percent) are among the special features of the Fogera breed. They are docile relative to other cattle types. Some body parts such as horn length and hump of the females relatively small than other cattle types (Figure 2).

Qualitative characteristics

Qualitative characters observed for male and female cattle of the three cattle types are presented in Table 4 (Figure 3).

Figure 2. Typical pure-Fogera breeding cow (a) and breeding bull (b).

Quantitative characteristics

Most of the dependent traits (mouth circumference, face length, horn length, neck length, dewlap length, dewlap width, height at wither, hump height, height at rump, body length, heart girth, body weight, heart girth around rump, rump length and tail length) were significant ($P \leq 0.01$) affected by sex. While horn space, ear length and pelvic width were not significant ($P \geq 0.05$) affected by sex, confirming the widely held notion that male and female populations have markedly different body form as measured in the quantitative variables. As a result, analyses of variance (ANOVAs) on quantitative variables were performed separately for the two sexes.

Effect of districts on linear body measurements of the population

Except horn length all of the quantitative traits (mouth circumference, face length, horn space, neck length, dewlap length, dewlap width, height wither, hump height, height at rump, body length, heart girth, body weight, heart girth at rump, pelvic width, rump length, scrotal length, udder length, teat length and tail length) were highly significantly ($P \leq 0.001$) affected by district.

Effect of breed type on linear body measurements of the population

Except some quantitative traits (horn length and horn space) all of quantitative traits (ear length, neck length, dewlap length, dewlap width, height at wither, hump height, height at rump, body length, heart girth, body weight, heart girth at rump, pelvic width, rump length for female, udder length, teat length, scrotal length and tail length) were highly significantly ($P \leq 0.001$); mouth circumference and face length ($P \leq 0.01$) and rump length for males ($P \leq 0.05$) affected by breed type on the population. Pairwise comparisons of the least-squares means between breeds (Table 5) showed that the sample populations of pure-Fogera cattle breed had the largest measurements for all traits except for horn length and horn space. Interbred with-Fogera cattle stood next to pure-Fogera in many measurements.

The result of the mean mouth circumference of the male and female pure-Fogera cattle were 42.68 ± 0.56 and 38.23 ± 0.18 cm, respectively. These results were larger

Table 4. Qualitative characteristics of male and female cattle population (%).

Traits		Breed type									
		Pure-Fogera						Interbred with-Fogera		Non-Fogera	
		On-farm		On-station		Overall					
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Hump size	Small	0	8.9	0	0	0	5.6	3.7	8.9	0	17.8
	Medium	44.4	91.1	0	100	34.78	94.4	44.4	91.1	77.8	82.2
	Large	55.6	0	100	0	65.22	0	51.9	0	22.2	0
Tail length	Short	0	1.1	0	0	0	0.7	0	6.7	3.7	2.2
	Medium	2.8	12.2	0	0	2.17	7.7	7.4	13.3	33.3	31.1
	Long	97.2	86.7	100	100	97.8	91.5	92.6	80.0	63.0	66.7
Dewlap size	Small	0	0	0	0	0	0	3.7	0	7.4	2.2
	Medium	8.3	52.2	0	11.5	6.52	37.3	7.4	60.0	29.6	66.7
	Large	91.7	47.8	100	88.5	93.48	62.7	88.9	40.0	63.0	31.1
Coat pattern	Plain	8.3	21.1	0	7.7	6.52	16.2	22.2	31.1	63.0	51.1
	Patchy	13.9	4.4	0	1.9	10.87	3.5	14.8	17.8	11.1	15.6
	Spotted	77.8	74.4	100	90.4	82.61	80.3	63.0	51.1	25.9	33.3
Coat color	White	5.6	17.8	0	5.8	4.35	13.4	7.4	8.9	11.1	15.6
	Red	0	0	0	0	0	0	7.4	11.1	22.2	28.9
	Black	2.8	3.3	0	1.9	2.17	2.8	7.4	11.1	29.6	8.9
	Red white	13.9	6.6	0	1.9	10.87	4.9	18.5	19.2	18.5	18.9
	Black white	27.8	27.8	80.0	42.3	39.13	33.1	7.4	8.9	7.4	4.4
	White black	50.0	41.1	20.0	46.2	43.48	43.0	51.9	35.6	11.1	13.3
Testicular size	Small	16.7		0		13.04		7.4		22.2	
	Medium	52.8		0		41.30		51.9		66.7	
	Large	30.6		100		45.65		40.7		11.1	
udder size	Small		31.1		0		19.7		33.3		40.0
	Medium		47.8		11.5		34.5		46.7		53.3
	Large		21.1		88.5		45.8		20.0		6.7
teat size	Small		16.7		0		10.6		31.1		24.4
	Medium		70.0		50.0		62.7		57.8		68.9
	Large		13.3		50.0		26.8		11.1		6.7

than those of Semien (34.18 and 33.41 cm), Wegera (39.60 and 36.80 cm), Dembia (34.14 and 32.64 cm), Fogera (37.60 and 34.95 cm) and Mahibere–Silassie composite (37.52 and 33.80 cm), respectively, breeds reported by Zewdu (2004).

The mean face lengths were 48.52 ± 0.50 and 45.89 ± 0.22 cm for males and females. This result was larger than Sheko breed (40.8 and 39.5 cm) reported by Takele (2005). The mean horn length of male and female pure-Fogera cattle were 16.35 ± 0.72 and 13.81 ± 0.37

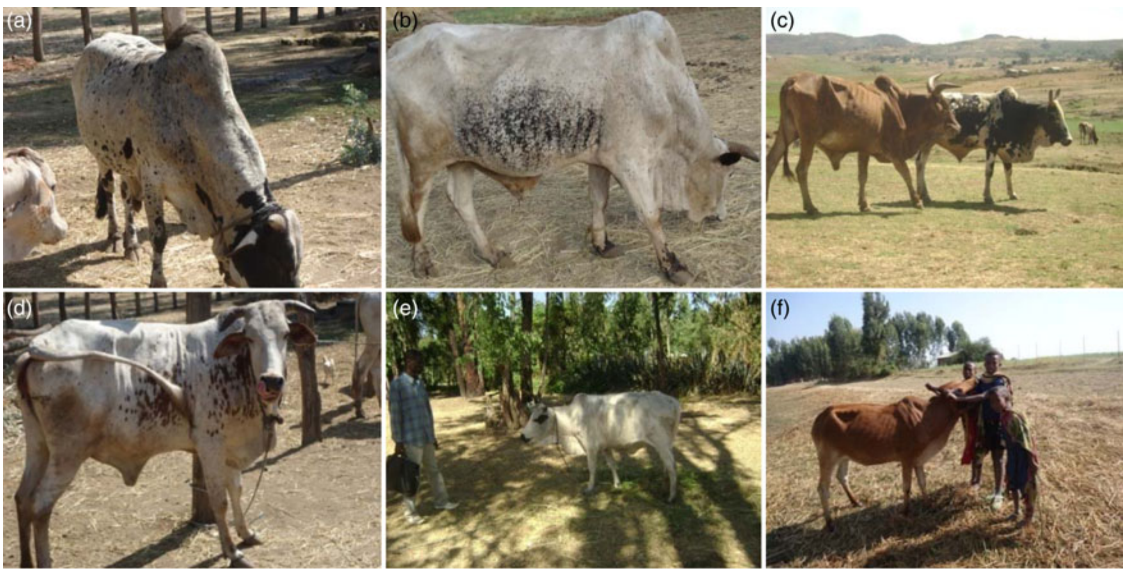

Figure 3. Physical variations in pure-Fogera (a, d), interbred with-Fogera (b, e) and non-Fogera (c, f) breed type at on-farm.

Table 5. Least-squares means ± SE and pair wise comparisons between breed types of linear body measurements (cm) for both sexes.

Breed type	MC		FL		HL		HS		EL	
	LSM ± SE		LSM ± SE		LSM ± SE		LSM ± SE		LSM ± SE	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Breed type	**	**	**	**	ns	ns	ns	ns	**	***
PF	42.68 ± 0.56^{a}	38.23 ± 0.18^{a}	48.52 ± 0.50^{a}	45.89 ± 0.22^{a}	16.35 ± 0.72	13.81 ± 0.37	14.63 ± 0.29	14.05 ± 0.16	24.87 ± 0.41^{a}	24.38 ± 0.21^{a}
IF	40.07 ± 0.44^{b}	37.38 ± 0.32^{b}	46.11 ± 0.57^{b}	44.62 ± 0.41^{b}	16.09 ± 0.83	14.93 ± 0.64	14.31 ± 0.33	14.26 ± 0.26	23.93 ± 0.37^{b}	22.99 ± 0.33^{b}
NF	40.33 ± 0.48^{b}	37.02 ± 0.34^{b}	44.93 ± 0.63^{b}	44.61 ± 0.27^{b}	15.74 ± 0.95	14.49 ± 0.62	14.28 ± 0.39	14.01 ± 0.26	22.94 ± 0.47^{c}	22.21 ± 0.33^{c}

Breed type	NL		DL		DW		HAW		HH	
	LSM ± SE		LSM ± SE		LSM ± SE		LSM ± SE		LSM ± SE	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Breed type	***	***	***	***	***	***	***	***	***	***
PF	44.74 ± 0.78^{a}	40.99 ± 0.34^{a}	95.43 ± 1.24^{a}	88.33 ± 0.42^{a}	37.04 ± 1.16^{a}	27.20 ± 0.42^{a}	129.17 ± 1.33^{a}	123.68 ± 0.52^{a}	18.24 ± 0.87^{a}	9.68 ± 0.14^{a}
IF	40.30 ± 0.62^{b}	38.67 ± 0.50^{b}	90.78 ± 1.06^{b}	85.53 ± 0.92^{b}	29.67 ± 0.95^{b}	24.38 ± 0.70^{b}	122.74 ± 1.13^{b}	119.58 ± 0.72^{b}	16.56 ± 1.03^{b}	8.32 ± 0.02^{b}
NF	39.33 ± 0.51^{b}	37.76 ± 0.38^{b}	87.22 ± 1.33^{c}	84.82 ± 0.83^{b}	26.70 ± 1.16^{c}	22.67 ± 0.75^{c}	121.04 ± 1.26^{b}	118.98 ± 0.74^{b}	12.48 ± 0.63^{c}	8.24 ± 0.23^{c}

Breed type	HAR		BL		HG		BW		HGAR	
	LSM ± SE		LSM ± SE		LSM ± SE		LSM ± SE		LSM ± SE	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Breed	***	***	***	***	***	***	***	***	***	***
PF	131.17 ± 1.18^{a}	126.59 ± 0.45^{a}	112.18 ± 1.36^{a}	106.69 ± 0.50^{a}	162.04 ± 2.03^{a}	148.75 ± 0.72^{a}	363.24 ± 12.87^{a}	280.21 ± 3.67^{a}	170.37 ± 2.41^{a}	160.32 ± 0.90^{a}
IF	125.78 ± 1.12^{b}	122.84 ± 0.82^{b}	106.11 ± 1.14^{b}	102.22 ± 0.74^{b}	149.15 ± 1.99^{b}	141.47 ± 1.40^{b}	283.70 ± 10.97^{b}	245.56 ± 6.96^{b}	157.70 ± 2.36^{b}	151.11 ± 2.15^{b}
NF	122.33 ± 1.34^{c}	122.24 ± 0.77^{b}	104.00 ± 1.28^{b}	102.20 ± 0.94^{b}	149.74 ± 1.88^{b}	142.53 ± 1.44^{b}	287.11 ± 11.18^{b}	250.73 ± 7.14^{b}	156.56 ± 2.19^{b}	153.22 ± 2.00^{b}

Breed type	PW		RL		SCROL	TAIL L		UDL	TEAL
	LSM ± SE		LSM ± SE		LSM ± SE	LSM ± SE		LSM ± SE	LSM ± SE
	Male	Female	Male	Female		Male	Female		
Breed type	***	***	*	***	***	***	***	***	***
PF	37.78 ± 0.61^{a}	37.12 ± 0.27^{a}	40.26 ± 0.60^{a}	38.53 ± 0.26^{a}	20.14 ± 1.37^{a}	88.93 ± 1.20^{a}	84.18 ± 0.54^{a}	18.21 ± 0.63^{a}	5.88 ± 0.12^{a}
IF	34.26 ± 0.76^{b}	35.60 ± 0.62^{b}	37.56 ± 0.93^{b}	36.72 ± 0.50^{b}	19.35 ± 1.37^{a}	85.52 ± 1.34^{b}	79.91 ± 1.03^{b}	13.51 ± 0.93^{b}	4.79 ± 0.21^{b}
NF	34.63 ± 0.62^{b}	34.31 ± 0.49^{b}	37.37 ± 0.65^{b}	36.36 ± 0.40^{b}	13.72 ± 1.06^{b}	81.22 ± 1.65^{c}	79.44 ± 0.88^{c}	12.31 ± 0.84^{b}	4.67 ± 0.15^{b}

ns, non-significant; *, $P \leq 0.05$; **, $P \leq 0.01$; ***, $P \leq 0.001$; SE, standard error.
MC, Mouth circumference; FL, Face length; HL, Horn length; HS, Horn space; EL, Ear length; NL, Neck length; DL, Dewlap length; DW, Dewlap width; HAW, Height at wither; HH, Hump height; HAR, Height at rump; BL, Body length; HG, Heart girth; BW, Body weight; HGAR, Heart girth around rump; PW, Pelvic width; RL, Rump length; SCROL, Scrotal length; UDL, Udder length; TEAL, Teat length and TAIL, Tail length.

cm. The mean horn length of male pure-Fogera cattle was shorter than Semien, Wegera, Llowland, Mahibere-Silassie and Gamo Goffa breeds (17.14, 19.84, 18.92, 17.30 and 17.86 ± 0.53 cm) reported by Zewdu (2004) and Chencha, Workneh and Zewdu (2013). However, the result was higher than Dembia and Fogera breeds (12.87 and 13.10 cm) reported by Zewdu (2004). However, the mean horn length of female was lower than Fogera breed (16.98 and 15.08 cm), Fipa cattle (28.92 ± 1.02 cm) reported by Zewedu (2004); Fasil and Workneh (2014) and Mwambene, Katule and Chenyambuga (2012), respectively.

The mean dewlap length of male and female pure-Fogera cattle were 95.43 ± 1.24 and 88.33 ± 0.42 cm, respectively. The dewlap length of the male was longer than Fogera breed (87 cm) reported by Rege and Tawah (1999). But the results dewlap length of the female was lower than Fogera breed (90 cm) reported by the same authors. The mean dewlap width (37.04 ± 1.16 and 27.20 ± 0.42 cm) were wider than Fogera (23.01 20.58 cm) and Mahibere–Silassie composite (25.50 and 24.08 cm) breeds reported by Zewedu (2004).

The mean height at wither (129.17 ± 1.33 and 123.68 ± 0.52 cm) of male and female pure-Fogera cattle were higher than Fogera breed (127 and 112 cm) reported by Rege and Tawah (1999). The mean body lengths (112.18 ± 1.36 and 106.69 ± 0.50 cm) of the male and female pure-Fogera cattle were lower than Fogera (124.39 and 119.77 cm), respectively, reported by Zewedu (2004).

The mean reported heart girths (162.04 ± 2.03 and 148.75 ± 0.72 cm) were shorter than Fipa cattle (164.24 ± 1.20 and 151.93 ± 1.11 cm) reported by Mwambene, Katule and Chenyambuga (2012). The mean tail length (88.93 ± 1.20 and 84.18 ± 0.54 cm) of the male and female pure-Fogera cattle were longer than Gam Goffa breeds (76.26 ± 0.39 and 72.35 ± 0.27 cm), Gozamen (78.04 and 72.54 cm) reported by Chencha, Workneh and Zewdu (2013) and Fasil and Workneh (2014).

Effect of sites/on-farm and on-station on linear body measurements of the population

Except horn length and horn space all of measurements for pure-Fogera cattle from on-station were significantly ($P \leq 0.001$) larger than those of the on-farm. Imply that the pure-Fogera cattle populations of on-station were much bigger than those of the on-farm. This may be because of genetic and environmental factors (Table 6).

Population structure and genetic diversity

Cattle population structure by age with breed type at the district level

The cattle flock in a purposive sampled herd population by age, breed type and sex in deferent Districts is present in Table 7. The structure of the population based on age and sexes were ox (15.51 percent), cow (28.39 percent), and bull (14.97 percent), heifers (22.99 percent), male calve (8.62 percent) and female calve (9.52 percent). According to this result cows and heifers had highest proportion than oxen, bulls and calves. This high proportion of cow and heifer is used for breeding purpose. Oxen were higher proportion than bulls and male calves. The proportions of female calves were greater than male calves.

Effective population size, inbreeding and heterozygosity of the population

The effective population size, inbreeding and heterozygosity of the Fogera cattle are indicated in Table 8. Effective population size is defined as the number of breeding individuals in an idealized population that would show the same amount of dispersion of allele frequencies under random genetic drift (Wright, 1922). A population that undergoes a severe temporary reduction in size (bottleneck) or when a small group of animals within the population establishes a new population (founder effect), the effective population size is closer to the number of animals at the point of maximum contraction than the number of animals at its census maximum. According to this study the effective population size of pure-Fogera cattle varies from district to district; however, the overall of effective population size were 4295. The effective population size in Fogera District was higher, while in Andassa Research Center the effective population size was lower. Falconer (1989) outlined the effects of inbreeding as: increase homozygosity (animals with a copy of the same allele at one locus); redistribution of genetic variances (decrease of within family genetic variance and increase of between family genetic variance); higher chance of appearance of lethal recessive genes in the homozygous state (BLAD), decrease of homeostasis (inbred animal less adaptive to environmental changes); and, reduction of the animals performance, particularly in terms of reproduction, fertility and health (inbreeding depression). The overall inbreeding level of Fogera cattle at F_1, F_2 and F_8 were lower with 0.012, 0.0024 and 0.1 percent, respectively. Thus, indicated that the average inbreeding level of Fogera cattle populations is low. The retained or expected hetrozygosity at F_8 was 99.9 percent.

Trait preference, breeding management and recommend breeding strategy

Trait preferences of Fogera breed

Table 9 shows the perceived evaluation by respondents on the most dominant traits of Fogera cattle. The milk yield (100 percent), colour (100 percent), power (100 percent), body size (99.2) and growth rate (96.8 percent) of Fogera were the most dominant traits perceived to be good by the respondents. While, fertility (76.2 percent) and others remaining traits were more than 50 percent preferred by the respondents.

Table 6. Least-squares means ± SE and pair wise comparisons between on-farm and on-situation of pure-Fogera cattle.

Site	MC		FL		HL		HS		EL	
	LSM ± SE		LSM ± SE		LSM ± SE		LSM ± SE		LSM ± SE	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Site	***	***	***	***	ns	Ns	ns	ns	*	***
On-farm	41.3 ± 0.49^{b}	37.7 ± 0.25^{b}	47.4 ± 0.43^{b}	44.8 ± 0.23^{b}	16.6 ± 0.86^{a}	14.2 ± 0.43^{a}	14.4 ± 0.33^{a}	14.2 ± 0.21^{a}	24.4 ± 0.46^{b}	23.2 ± 0.24^{b}
On-station	47.6 ± 0.75^{a}	39.1 ± 0.20^{a}	52.4 ± 0.97^{a}	47.8 ± 0.30^{a}	15.3 ± 1.19^{a}	13.1 ± 0.68^{a}	15.4 ± 0.54^{a}	13.8 ± 0.22^{a}	26.6 ± 0.67^{a}	26.4 ± 0.20^{a}
Site	NL		DL		DW		HAW		HH	
	LSM ± SE		LSM ± SE		LSM ± SE		LSM ± SE		LSM ± SE	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Site	***	***	***	*	***	***	***	***	***	***
On-farm	42.8 ± 0.72^{b}	39.2 ± 0.39^{b}	$92.8 \pm {}^{b}1.25$	87.7 ± 0.61^{b}	34.4 ± 0.97^{b}	25.4 ± 0.51^{b}	126.0 ± 1.19^{b}	120.8 ± 0.56^{b}	16.6 ± 0.85^{b}	9.0 ± 0.19^{b}
On-station	51.8 ± 0.53^{a}	44.0 ± 0.35^{a}	104.9 ± 0.80^{a}	89.4 ± 0.39^{a}	46.7 ± 2.06^{a}	30.3 ± 0.51^{a}	140.6 ± 1.51^{a}	128.8 ± 0.53^{a}	24.1 ± 1.54^{a}	10.8 ± 0.11^{a}
Site	HAR		BL		HG		BW		HGAR	
	LSM ± SE		LSM ± SE		LSM ± SE		LSM ± SE		LSM ± SE	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Site	***	***	***	***	***	***	***	***	***	***
On-farm	128.4 ± 1.08^{b}	124.2 ± 0.54^{b}	109.8 ± 1.45^{b}	104.1 ± 0.93^{b}	157.7 ± 1.97^{b}	146.0 ± 0.93^{b}	333.9 ± 11.59^{b}	266.3 ± 4.63^{b}	165.7 ± 2.42^{b}	157.9 ± 1.27^{b}
On-station	141.1 ± 1.25^{a}	130.7 ± 0.51^{a}	120.9 ± 1.46^{a}	111.4 ± 0.39^{a}	177.6 ± 2.40^{a}	153.6 ± 0.80^{a}	469.0 ± 18.43^{a}	304.4 ± 4.33^{a}	$187.2^{a} \pm 3.38$	164.5 ± 0.86^{a}

Site	PW		RL		SCROL	TAIL L		UDL	TEAL
	LSM ± SE		LSM ± SE		LSM ± SE	LSM ± SE		LSM ± SE	LSM ± SE
	Male	Female	Male	Female		Male	Female		
Site	***	***	***	***	***	***	***	***	***
On-farm	36.6 ± 0.63^{b}	35.7 ± 0.29^{b}	39.0 ± 0.61^{b}	37.2 ± 0.30^{b}	16.7 ± 1.14^{b}	86.6 ± 1.10^{b}	82.4 ± 0.70^{b}	14.5 ± 0.73^{b}	5.4 ± 0.13^{b}
On-station	42.0 ± 0.62^{a}	39.5 ± 0.33^{a}	44.8 ± 0.57^{a}	40.9 ± 0.29^{a}	32.4 ± 1.86^{a}	97.3 ± 2.45^{a}	87.3 ± 0.68^{a}	24.6 ± 0.42^{a}	6.7 ± 0.17^{a}

ns, non-significant; *, $P \leq 0.05$; ***, $P \leq 0.001$; SE, standard error.
[a,b]Least-squares means with different superscripts within a row are significantly different at $P \leq 0.001$ and $P \leq 0.05$.

Table 7. Cattle flock structure by age, breed tye and sex groups in different Districts in a sampled open population (%).

Age class	Breed type	Dembia	Libo	Fogera	Bahir Dar Zuria	Overall
	Pure-Fogera	62 (2.94)	47 (3.95)	352 (5.10)	0 (0)	461 (4.32)
Ox	Interbred-Fogera	76 (3.60)	60 (5.04)	453 (6.56)	0 (0)	589 (5.52)
	Non-Fogera	149 (7.06)	56 (4.70)	401 (5.81)	0 (0)	606 (5.68)
Subtotal		287 (13.60)	163 (13.69)	1206 (17.47)	0 (0)	1656 (15.51)
	Pure-Fogera	133 (6.30)	131 (11.00)	763 (11.05)	167 (35.46)	1194 (11.19)
Cow	Interbred-Fogera	207 (9.81)	143 (12.01)	609 (8.82)	27 (5.73)	986 (9.24)
	Non-Fogera	371 (17.57)	110 (9.24)	370 (5.36)	0 (0)	851 (7.97)
Subtotal		711 (33.68)	384 (32.24)	1742 (25.24)	194 (41.19)	3031 (28.39)
	Pure-Fogera	73 (3.46)	49 (4.11)	499 (7.23)	19 (4.03)	640 (6.01)
Bull	Interbred-Fogera	77 (3.65)	52 (4.37)	423 (6.13)	0 (0)	552 (5.17)
	Non-Fogera	110 (5.21)	43 (3.61)	251 (3.64)	2 (0.42)	406 (3.80)
Subtotal		260 (12.32)	144 (12.09)	1173 (17.0)	21 (4.46)	1598 (14.97)
	Pure-Fogera	68 (3.22)	116 (9.74)	697 (10.10)	81 (17.20)	962 (9.01)
Heifer	Interbred-Fogera	116 (5.50)	99 (8.31)	577 (8.36)	18 (3.82)	810 (7.59)
	Non-Fogera	245 (11.61)	84 (7.05)	353 (5.11)	0 (0)	682 (6.39)
Subtotal		429 (20.32)	299 (25.11)	1627 (23.57)	99 (21.02)	2454 (22.99)
	Pure-Fogera	30 (1.42)	30 (2.52)	199 (2.88)	69 (14.65)	328 (3.07)
Male calve	Interbred-Fogera	47 (2.23)	37 (3.11)	233 (3.38)	6 (1.27)	323 (3.03)
	Non-Fogera	95 (4.50)	23 (1.93)	151 (2.19)	0 (0)	269 (2.52)
Subtotal		172 (8.15)	90 (7.56)	583 (8.45)	75 (15.92)	920 (8.62)
	Pure-Fogera	58 (2.75)	53 (4.45)	217 (3.14)	65 (13.80)	393 (3.68)
Female calve	Interbred-Fogera	69 (3.27)	32 (2.69)	222 (3.22)	17 (3.61)	340 (3.19)
	Non-Fogera	125 (5.92)	26 (2.18)	132 (1.91)	0 (0)	283 (2.65)
Subtotal		252 (11.94)	111 (9.32)	571 (8.27)	82 (17.41)	1016 (9.52)
Total by sex	Male	719 (34.06)	397 (33.33)	2962 (42.92)	96 (20.38)	174 (39.10)
	Female	1392 (65.94)	794 (66.67)	3940 (57.08)	375 (79.62)	6501 (60.90)
	Pure-Fogera	424 (20.09)	430 (36.10)	2697 (39.08)	401 (85.14)	3952 (37.02)
Total by breed	Interbred-Fogera	590 (27.95)	423 (35.52)	2517 (36.47)	68 (14.44)	3598 (33.71)
	Non-Fogera	1118 (52.96)	342 (28.72)	1658 (24.02)	2 (0.42)	3120 (29.23)

Special qualities of Fogera breed

Colour quality (100 percent), milk yield (100 percent), growth rate (100 percent), body conformation (100 percent), swimming ability (100 percent) and disease resistance (98.4 percent) were the most frequently reported special qualities of the Fogera breed type differ from other indigenous breeds in their natural habitat (Table 10).

Adaptation levels of Fogera breed

Fogera breed possess unique adaptive traits that enabled them survive, produce and reproduce in that very challenging environment. The special qualification of this breed is to live at high amount of flooding areas. Most of the respondents reported that their cattle had good level of tolerance/resistance for most of the adaptive traits except with stand to water shortage considered in this study that ranges from 29.37 percent for with stand to water shortage tolerance to 100 percent tolerate swampy grazing or ability to tolerate swampy graizing lands of the area (Table 11).

Breeding management

Breeding practice

In the study districts, all of the respondents were practice pure breeding of Fogera, interbred with Fogera and non-Fogera type of breeds. This is in agreement with the result of Shiferaw (2014) and Alemu, Ayenalem and Tadele (2012) who are indicated that in Fental district of Oromia region and in Horro District of Western Oromia, 92.7 and 92.7 percent respondents are practiced pure breeding system for Kereyu and Horro cattle types. Most of the respondents reported that the pure-Fogera breed type was more preferable. In some PA such as Wagetera,

Table 8. Effective population size, inbreeding and heterozygosity of the Fogera cattle.

Measurement	Dembia	Libo	Fogera	Andasa	Total
Effective population size (*Ne*)	865	998	2295	71	4295
The rate of inbreeding (ΔF)	0.06%	0.05%	0.02%	0.70%	0.012%
The expected IC					
Inbreeding coefficient at F_1	0.06%	0.05%	0.02%	0.70%	0.012%
Inbreeding coefficient at F_2	0.12%	0.1%	0.04%	0.14%	0.024%
Inbreeding coefficient at F_8	0.48%	0.4%	0.2%	0.56%	0.1%
Expected heterozygosity (RH) at F_8	99.5%	99.6%	99.8%	99.44%	99.9%

Table 9. Trait preferences for Fogera breed by respondents.

Traits	Respondents ($N = 126$)	
	Frequency	%
Milk yield	126	100
Colour	126	100
Power/draught	126	100
Body size	125	99.2
Fertility	96	76.2
Growth rate	122	96.8

Table 11. Adaptation levels of Fogera breed.

Traits	Level of tolerance ($N = 126$)		
	Good (%)	Moderate (%)	Less (%)
Heat tolerance	72.22	27.78	0
Drought tolerance	63.49	35.71	0.79
Withstand to feed shortage	80.16	19.84	0
Withstand to water shortage	29.37	52.38	18.25
Disease resistance	83.33	16.67	0

the pure-Fogera bulls were disseminated by the Andassa Livestock Research Center and those bulls were used for breeding purpose in that PA by group. As reported by the respondent's one breeding Fogera bull mate with up to 100 females of the respondents and then the representative of the bull can use this bull as your either mating or power.

Mating system

All of the respondents reported natural mating with selected bull mating system. This report was related with Alemu, Ayenalem and Tadele (2012) report in Horro District. All of the respondents preferred pure breeding using Fogera bulls for mating. Additionally, most (97.6 percent) of the respondents had a good perception for pure-Fogera breed dissemination with 54.8 percent female Fogera cattle prefer and 41.3 percent both female and male sex. In addition to these most of (88.9 percent) the respondents had a positive attitude on AI service by pure-Fogera breed.

Source of breeding bulls and purpose of keeping them

Most (95.2 percent) of the respondents were reported use both own herd and neighbouring herd bulls during communal grazing. The remaining (4 percent) respondents depend on their bull from own herd. Some respondents (0.8 percent) were depended on the neighbouring bulls for mating their cows particularly in the communal grazing areas. Most (91.3 percent) of the respondents reported that they kept breeding bulls for mating purpose. While a few

Table 10. Special qualities of Fogera breed.

Special quality trait	Respondent ($N = 126$)	
	Frequency	%
Disease resistance	124	98.4
Drought tolerance	104	82.5
Colour quality	126	100
Heat tolerance	90	71.4
Walk ability	99	78.6
Milk yield	126	100
Growth rate	126	100
Body conformation	126	100
Docile/passiveness	106	84.1
Fertility	115	91.3
Good mothering	78	61.9
Resistance of flood/swimming ability	126	100

(8.7 percent) of them kept bulls both for mating draught purposes. This is in agreement with the result of Alemu, Ayenalem and Tadele (2012) and Jiregna (2007) in Horro District of Western Oromia and Danno District who indicated that farmers in the districts did not keep breeding bull only for mating rather they use both for breeding and draught power. These reports were also related with Fipa cattle in the southwestern highlands of Tanzania (Mwambene, Katule and Chenyambuga, 2012).

Culling method

Cattle owners in the study districts have developed a culling mechanism for maintaining the desired quality of their cattle. Culling of male cattle is generally done when age increase and their power and feeding ability decrease. However, female cattle are culled from the breeding stock after at age of 13 and above. The primary reason for culling animals from herd were old age, reproductive failure, reduction of production performance, health problem, need for some cash for household use and need for slaughter. Both selling and castration, all three types of culling (selling, castration and slaughter), castration and selling account for 35.7, 35.7, 27 and 1.6 percent of culling methods, respectively. These reports were agreed with Alemu, Ayenalem and Tadele (2012) report in Fental District of Oromia region.

Heat detection methods and signs of heat

All 100 percent of the respondents were reported to practice heat detection through visual observation. The rank of heat detection method is shown in Table 12. Clear mucus discharge (0.162 index value), red swollen vulva (0.160 index value), stands to be mounted (0.129 index value). Smells other cow (0.124 index value) and stands and bellows (0.102 index value) were among the frequently reported signs of heat in the study areas. According to this result, respondents were identified more their heat cow by observation signs of clear mucus discharge, red swollen vulva, stands to mounted and smells other cow from unheated cow.

Consideration during selecting breeding animals

Accordingly, milk production (100 percent), colour (100 percent), body size (100 percent), adaptability (98.41 percent), growth rate (96.83 percent), perpetual sheath (74.60 percent), navel flap (73.02 percent), perpetual sheath (86.8 percent), fertility (83.3 percent) and long tail (70.63

Table 12. Overall method of heat detection of the respondents.

Method of heat detection	Rank (frequency) $N=126$										Index value
	1	2	3	4	5	6	7	8	9	10	
Smells other cow	20	6	20	26	19	15	10	5	2	3	0.124
Stands & bellows	0	8	6	28	30	23	14	7	7	3	0.102
Head butts other	0	1	0	4	3	10	13	24	31	40	0.048
Attempts to ride other cow	0	1	8	7	8	11	22	25	19	25	0.066
Red swollen vulva	37	62	16	4	2	2	2	0	0	1	0.160
Clear mucous discharge	62	35	10	5	5	3	1	3	2	0	0.162
Stands to be mounted	6	11	53	19	22	6	4	3	1	1	0.129
Rides other cow	0	1	4	5	6	14	18	18	33	27	0.059
Bellows frequently	0	0	6	2	17	18	21	28	22	12	0.068
Nervous and excitable	1	1	3	26	14	24	21	12	9	15	0.083

percent) were among the considered traits while selection (Table 13).

Major breeding problems in the study area: Reported major breeding problems that affect the productivity of the animals are shown in Table 14. Late age at first calving (100 percent), long calving interval (100 percent), unavailability of feed (100 percent) disease and parasite (99.21 percent) and *post-partum* anoestrus (95.24 percent) were among the listed major breeding problems reported by the respondents.

Recommend breeding strategy

According to phenotypic characterization of this study mixed farming (livestock–crop) production system is the existing production system in the study areas. The main purposes of keeping Fogera cattle are for milk, draught/power, source of income and manure. In addition to this their reproductive performances is good even many reproductive performance constraints found in the study areas. When we see the production performance, Fogera cattle have high daily milk yield of first, second and third parity of early, mid and late stages. Milk yield, colour, power, large body size and their growth rate are the main trait preference by the respondent. This breed has special qualities in disease resistance, drought tolerance, heat tolerance and resistance of flood/swimming ability. According to the respondents this breed has special qualities that are suitable for production by resisting many environmental problems in the areas. Pure breeding of pure-Fogera, cross-Fogera and non-Fogera types of breeds is practiced in the study areas. Late age at first calving, long calving interval, unavailability of feed and disease and parasite are the major breeding problems in the areas. However, feed shortage and disease and parasites are the main causes for late age at first calving and long calving interval. The main causes of feed shortage and disease and parasite in the areas are rice cultivation and flooding, respectively. Feed shortage in the areas occurs all months of the year. But from May to October the scarcity of feed is high. Feeding conserved feed is the main response by the respondents during feed shortage period. According to morphological characterization, Fogera cattle has special physical character (hump size, dewlap size, coat pattern, coat colour, testicular size, udder size, teat size and tail length) and larger body size.

According to population structure of on-farm cattle population, a non-Fogera, cross-Fogera and pure-Fogera cattle accounts about 35.23, 33.31 and 31.76 percent, respectively. This indicated that how much decrease the population of pure – Fogera cattle in the study area by the admixture with other indigenous cattle breeds and their population is lower than both cross-Fogera and non-Fogera cattle population.

Table 13. Consideration during selecting breeding animals by respondents.

Traits	Respondents ($N=126$)	
	Frequency	%
Milk yield	126	100
Color	126	100
Body size	126	100
Naval flap	92	73.02
Perpetual sheath	94	74.60
Fertility	81	64.29
Long tail	89	70.63
Prenatal history	81	64.29
Growth rate	122	96.83
Adaptability	124	98.41
Temperament	30	23.81
Scrotal size	82	65.08

Table 14. Major breeding problems in the study area.

Major breeding problems	Respondents ($N=126$)	
	Frequency	%
Late age at first calving	126	100
Post-partum anoestrus	120	95.24
Long calving interval	126	100
Unavailability of feed	126	100
Disease and parasite	125	99.21
Abortion	16	12.70
Calving difficulty	8	6.35
Lack of selected breeding bull	89	70.63

According to the population viability the current phenotypic pure-Fogera breed population was low (9016) and drastically decreasing with highly cross-breeding with other indigenous breeds. The population viability analysis showed that the current population (9016) will decline to 300 animals within 162.7 years with both 0 lower confidence and 162.7 years upper confidence limits. Generally the phenotypic characterization and population viability analysis results indicated that how much Fogera breed is suitable by the farmers by resisting many things and because of many problems the purity is decreasing radically. So in order to sustain this breed for the future generation appropriate breeding strategy is mandatory. When designing a breeding strategy the existing production system and the objective of the operation should be clearly known and defined. According to this the breeding objective of our study is in addition to improving the contribution the breed can make to the livelihood of producers and the economy of the country, to improve the population status of pure-Fogera breed and reduce risk on the breed by avoiding cross-breeding with other indigenous breeds. To fulfil this breeding objective selection within breed strategy and control breeding with *in situ* conservation strategy at the on-farm level and open-nuclus breeding with *ex situ* conservation strategy at the Andassa Research Center (on-station) level are the recommended breeding strategy by this study. Open-nucleus breeding scheme (ONBS) is a scheme which allows an in-flow of high potential breeding animals (Philipsson *et al.*, 2006) from lower-tier herds for pure-breeding to nucleus herds in the ranches as a strategy for genetic improvement of cattle breed in Ethiopia. In order to fulfil this strategy we recommend follow the following steps of breeding tools:

1. Selection of the animals
2. Test performance of the animal
3. Genetic evaluation
4. Multiplication or reproduce
5. Dissemination of the improved genotypes
6. Monitoring
7. Evaluation based on the objective.

Conclusion and recommendation

Based on the findings obtained from the study, it was possible to conclude that the Fogera breed is found only at selected villages and PAs of Dembia, Libo and Fogera Districts at on-farm level and in Andassa Livestock Research Center at the on-station level in a pure form and various level of admixture with other indigenous cattle breeds. However the level of admixture, structure of the population and population sizes vary between districts. Generally the population growth trends of pure-Fogera cattle are at highly decreasing trend. Qualitative and quantitative traits study result indicated that high variation between the three cattle populations (pure-Fogera, interbred with-Fogera and non-Fogera) and between on-station and on-farm. Both sexes of pure-Fogera breed had large body size and dominated by the spotted coat pattern with dominated white black or black white coat colour. Both sexes of this breed had higher mean values in the most quantitative traits compared with both Interbred with Fogera and non-Fogera breeds. Similarly, on-station pure-Fogera breed had higher mean values in all quantitative traits except horn length and horn space compared with on-Farm pure-Fogera breed.

The structure of pure Fogera cattle population in the on farm study districts were indicated highly admixture with other indigenous breeds. However, the pure Fogera cattle population statuses were difference from district to district, PA to PA and villages to villages. According to this study Fogera District had high pure-Fogera cattle populations (39.08 percent). However, the population of pure-Fogera population in Dembia District was lower (20.09 percent). According to the age structure of the pure-Fogera cattle population ox, cow, bull, heifer, male and female calves were accounted 4.32, 11.19, 6.01, 9.01, 3.68 and 3.68 percent, respectively. According to this study the population of pure-Fogera cows was higher than the rest age class. This higher breeding cows and heifers used for breeding purpose other than males. In this study, the females were higher than males with 60.90 and 39.10 percent, respectively.

Fogera breed can be used for multipurpose production. Our own results indicate that growth and reproductive performance of the breed are too good compared with some indigenous breeds and this attributes make Fogera cattle very good multipurpose animal.

The preferred performance traits and desirable qualities of Fogera breed in the different study Districts reflected their relative economic value in their respective localities. Milk yield performance, colour, body size, growth rate and fertility were preferred in all districts. Consideration of breeding cattle by the respondents related with the special qualities of Fogera breed. These indicated that Fogera breed is high preferable by the farmers than other indigenous breeds. According to the literature and our result Fogera breed is known by the following special qualities from the other indigenous breed; their colour, milk yield, growth rate, body conformation, disease resistance, fertility and docile/passive. The level tolerance of traits (withstand to feed shortage, disease resistance, parasite tolerance, heat tolerance and drought tolerance) were good. While, tolerance level of withstand to water shortage was less. Additional well designed genetically studies to provide evidence for this is therefore warranted and recommended.

Natural mating with pure-breeding is the essential mating practice in the study districts. Late age at first calving, *post-partum* anoestrus, long calving interval, unavailability of feed, disease and parasite and lack of selected breeding bull were the major reported breeding problems in the study districts. In addition to this the population structure and the population viability of Fogera breed population indicated highly inter-crossing and radically decrease.

Therefore to minimizing risk factors for conservation and sustainable utilization of the Fogera cattle:

- The level of genetic dilution of Fogera cattle type with the other indigenous cattle in the study districts as well as PA and village levels needs further study.
- The reported level of pure-Fogera cattle population were higher in some study villages, so to conserve the breed for the future any responsible agents or organizations apply close monitoring in those high pure-Fogera cattle potential villages.
- So, the recommended breeding strategy by this study and other appropriate breeding strategy must be apply without delay in order to conserve the breed from the risk.

Acknowledgements

We would like to thank the farmers, Development agents, Agricultural office workers of Denbia, Libo kemkem, Fogera Districts and Andassa livestock research Center for their cooperation during data collection. We would like to thank also Bahir Dar University, Biotechnology Research institute and Ethiopian biodiversity research institute for funding this research.

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Animal Genetic Resources, 2016, 58, 31–42. © Food and Agriculture Organization of the United Nations, 2016
doi:10.1017/S2078633616000060

Comparative reproductive performance evaluation of Holstein Friesian cattle breeds in two different agro ecological conditions, Oromia region, Ethiopia

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Summary
Comparative study was conducted at Alage and Ardaita Agricultural Technical and Vocational Education Training College dairy farm to evaluate the reproductive performance of Holstein Friesian (HF) and associated factors in the two farms. The data collected from 2000 to 2015 on reproductive traits ($n = 1688$) were analyzed using general linear model procedures of SAS version 9.2 (SAS, 2008). The result revealed that an overall least square means and standard errors for Age at first Service (AFS), Age at first calving (AFC), Calving interval (CI), Days open (DO) and Number of services per conception were 29.70 ± 0.49 months, 39.75 ± 0.53 months, 465.76 ± 7.22 days, 188.11 ± 7.22 days and 1.31 ± 0.04, respectively. AFC was significantly influenced by agro ecology ($P < 0.001$) and year of birth ($P < 0.01$). Besides this, agro ecology ($P < 0.001$) and year of birth ($P < 0.05$) was significantly influenced by AFC. Year of calving and parity had significant effect ($P < 0.001$) on CI and DO. Except CI, agro ecology had significant effect on all traits. Service per conception was significantly influenced by agro ecology ($P < 0.05$) and year of calving ($P < 0.01$). Season of birth and season of calving was not significant on all reproductive traits. Except SPC, the result obtained for AFS, AFC, CI and DO were below the standard expected from commercial dairy farm. Poor efficiency of estrus detection and expression were the most probable management factors accounted for longer period of AFS, AFC, CI and DO. Improving the level of nutrition as well as efficiency of estrus detection system is required for optimal reproduction performance of HF breed in the area.

Keywords: *Agro ecology, Holstein Friesian, reproductive performance*

Résumé
Une étude comparative a été menée dans les fermes des Écoles de Formation Agricole d'Alage et d'Ardaita afin d'évaluer les performances de reproduction et autres paramètres associés chez la race Holstein-Frisonne. Les données de reproduction ($n = 1688$), recueillies entre 2000 et 2015, ont été analysées en utilisant la procédure du modèle linéaire généralisé du logiciel SAS version 9.2 (SAS, 2008). Les analyses ont décelé que, dans l'ensemble, les moyennes des moindres carrés et les erreurs-types pour l'âge à la première insémination (API), l'âge au premier vêlage (APV), l'intervalle entre vêlages (IV), le nombre de jours ouverts (NJO) et le nombre d'inséminations par fécondation (NIF) ont été de 29,70 ± 0,49 mois, 39,75 ± 0,53 mois, 465,76 ± 7,22 jours, 188,11 ± 7,22 jours et 1,31 ± 0,04, respectivement. L'API a été significativement affecté par l'agro-écologie ($p < 0,001$) et par l'année de naissance ($p < 0,01$). Par ailleurs, l'agro-écologie ($p < 0,001$) et l'année de naissance ($p < 0,05$) ont aussi influencé significativement l'APV. L'année de vêlage et le rang de gestation ont eu un effet significatif ($p < 0,001$) sur l'IV et le NJO. Hormis l'IV, l'agro-écologie a eu un effet significatif sur tous les paramètres. Le NIF a été significativement affecté par l'agro-écologie ($p < 0,05$) et par l'année de vêlage ($p < 0,01$). La saison de naissance et la saison de vêlage n'ont affecté significativement aucun des paramètres reproductifs. Excepté le NIF, les résultats obtenus pour l'API, l'APV, l'IV et le NJO ont été inférieurs à la norme des exploitations laitières commerciales. La faible efficacité de détection des chaleurs a été probablement le principal facteur d'élevage expliquant l'allongement de l'API, de l'APV, de l'IV et du NJO. L'amélioration du niveau nutritionnel ainsi que celle de l'efficacité de la détection des chaleurs s'avèrent nécessaires pour atteindre des performances de reproduction optimales chez la race Holstein-Frisonne dans la zone.

Mots-clés: *agro-écologie, Holstein-Frisonne, performances de reproduction*

Resumen
Se llevó a cabo un estudio comparativo en las granjas de las Escuelas de Formación Agraria de Alage y Ardaita para evaluar los resultados reproductivos y otros parámetros asociados en ganado Frisón (Holstein). Los datos reproductivos ($n = 1688$), tomados entre 2000 y 2015, fueron analizados usando el procedimiento del modelo lineal generalizado del programa SAS versión 9.2 (SAS, 2008). Los análisis arrojaron que, en conjunto, las medias por mínimos cuadrados y los errores estándares para la edad a la primera inseminación (EPI), la edad al primer parto (EPP), el intervalo entre partos (IP), los días abiertos (DA) y el número de inseminaciones por gestación (NIG) fueron de 29,70 ± 0,49 meses, 39,75 ± 0,53 meses, 465,76 ± 7,22 días, 188,11 ± 7,22 días y 1,31 ± 0,04, respectivamente. La EPI se vio significativamente afectada por la ecología del sistema agrícola ($p < 0,001$) y por el año de nacimiento ($p <$

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0,01). Asimismo, la ecología del sistema agrícola ($p < 0{,}001$) y el año de nacimiento ($p < 0{,}05$) también influyeron significativamente sobre la EPP. El año y el número de parto tuvieron un efecto significativo ($p < 0{,}001$) sobre el IP y los DA. Exceptuando el IP, la ecología del sistema agrícola tuvo un efecto significativo sobre todos los parámetros. El NIG se vio significativamente afectado por la ecología del sistema agrícola ($p < 0{,}05$) y por el año de parto ($p < 0{,}01$). La época de nacimiento y la época del parto no afectaron significativamente a ninguno de los parámetros reproductivos. Salvo el NIG, los resultados obtenidos para la EPI, la EPP, el IP y los DA estuvieron por debajo de los estándares esperados en explotaciones lecheras comerciales. La escasa eficiencia en la detección de los celos fue probablemente el principal factor de manejo responsable del alargamiento de la EPI, la EPP, el IP y los DA. La mejora del nivel nutricional así como de la eficiencia en la detección de los celos se hace necesaria para alcanzar unos resultados reproductivos óptimos en el ganado Frisón de la zona.

Palabras clave: *ecología del sistema agrícola, Frisona-Holstein, resultados reproductivos*

Submitted 12 October 2015; accepted 13 April 2016

Introduction

Ethiopia has the largest livestock population in Africa and is estimated to be 53.99 million heads of cattle. Out of this, the female cattle constitute about 55.48 percent and the remaining 44.52 percent are male cattle (CSA, 2012/2013). Livestock production constitutes to be an important sub-sector of the agricultural production in Ethiopia, contributing 45 percent of the total agricultural gross domestic product (IGAD, 2010). Livestock sector has a significant contribution to the Ethiopian economy but production per animal is extremely low (Kumar & Tkui, 2014).

Increasing the number of animals is not a desirable proposition as the land resources of the country are very limited and cannot afford allocating more land under fodder production. As a result, productive and reproductive traits are crucial factors determining the profitability of dairy production (Lobago, 2007). More effective approach to increase production can be improving environmental condition and management practices coupled with improving genetic potential of dairy animals (Lateef, 2007).

Besides their genotype, the performance of dairy animals is also affected by many environmental factors. These environmental factors may suppress the animal's true genetic ability and create a bias in the selection of animals (Lateef *et al.*, 2008). The periodical evaluation of factors affecting productivity of animals is very important for future planning and management. Hence, there is a need to periodical evaluation of reproductive performance of dairy cattle and factors affecting their performance. Exotic dairy breeds have been introduced from time to time in Ethiopia, a herd of Holstein Friesian (HF) cattle are maintained at Alage and Ardaita dairy farms. At present both farms are the major farms consisting mainly of Holstein dairy herds established with the aim to fulfil the ever increasing demands of milk and milk products to the college and surrounding community. Performance of these animals is affected by many genetic and non-genetic factors. Production can be increased by increasing the number of animals or improving production per animal through better environment and management practices. Therefore, the main objective of this study was to evaluate comparatively the reproductive performance of HF dairy cattle maintained at the two different agro ecological systems.

Materials and methods

Description of the study area

The study was conducted at Alage and Ardaita Agricultural technical vocational educational training (ATVET) Colleges (Figure 1), which is the federally administered colleges under the Ministry of Agriculture and Rural Development (MoARD) (2012).

Alage college

Alage college is located at 217 km southwest of Addis Ababa, in the vicinity of the Abijata and Shala lakes of the Ethiopian Rift Valley. The farm rests on 4 200 ha of land, at a longitude of 38° 30 east and a latitude of 7°30′ north, with an altitude of 1 600 m a.s.l. The area is characterized by mild tropical weather with a minimum and maximum temperature ranging from 11 to 32 °C and experiences a bimodal rainfall distribution with an annual average of 800 mm.

Ardaita college

Ardaita college is located about 305 km southeast of Addis Ababa in Gedeb Asasa district, West Arsi Zone of Oromia National Regional State, encircled with farmlands at an altitude of 2410–2610 m a.s.l. with 4°17′20″ north latitude and 37°11′30″ east longitude in south eastern Ethiopia of Oromia National Regional State in the high land of Arsi zone. Gedeb Asasa is bordered on the south by the Dodola, on the west by Kofele, on the North West by Kore and on the north east by Bekoji. It has a total land area of 1613 ha of land. The mean annual rain fall is 1200 mm and maximum and minimum temperature ranges between 20 and 5 °C, respectively.

Based on agro climatic condition and rainfall both area has three distinct seasons. A short rainy season, which extends

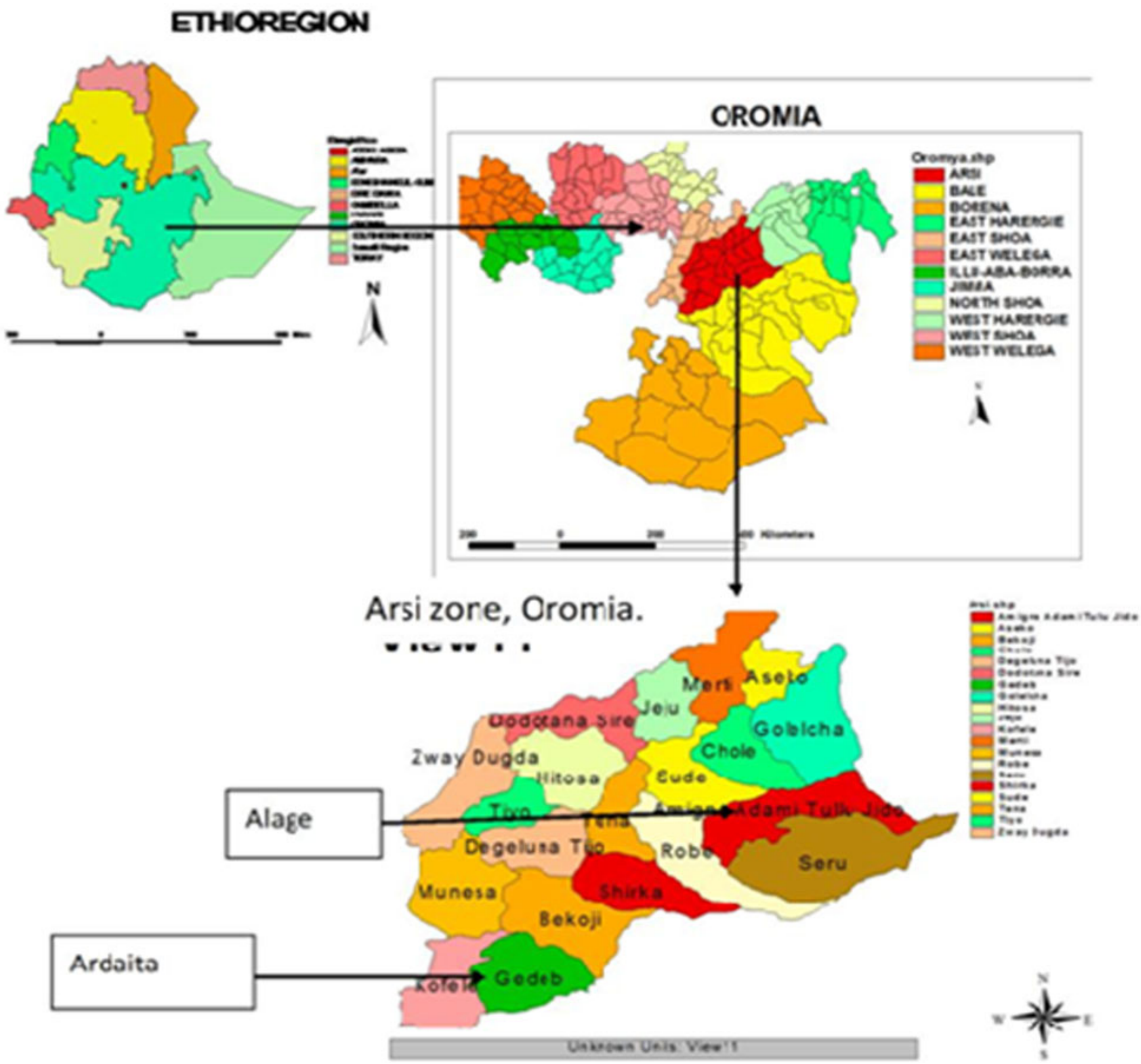

Figure 1. Map of Ethiopia (top write), part of Oromia (top left) and parts of Arsi zone (bottom) indicating the study site Alage and Ardaita ATVET college.

from March to June, a long rainy season, which extends from July to October and a dry season that extends from November to February (NMSA, 2010).

Establishment of the farm and breed groups

Alage dairy farm started its dairying activity in 1980 with foundation stock of 300 females and four males of HF origin brought from the Stella dairy farm, Holetta and individual farms around Addis Ababa. While, the Ardaita dairy farm was established in 1984 by purchasing 50 first crosses of Friesian with Boran from Gobe agricultural development unit. The Alage dairy farm was consisted mainly of HF cattle population, while Ardaita dairy farm was engaged with HF and its crosses with Boran cattle breeds to produce milk and milk products to fulfill the ever increasing demand for milk and milk products in the area.

Animal management

Animals were maintained under intensive systems and herds are managed separately based on sex, age, pregnancy and lactation. Animals were stall fed individually with green fodders and roughages, concentrates also fed to the animals according to the daily nutrient requirements for different categories of animals. Heifers and dry cows were mainly fed on green fodder and other roughages throughout the year. At both farms artificial insemination was practiced by bringing pure HF semen from national artificial insemination center. The insemination practice was carried out by AI technicians. Detection of estrus was carried out twice a day, early in the morning and late in the afternoon.

Cows grazed on native pastures during the rainy season from 1 a.m. to 3 a.m. local time. After that the animals are tied and stall fed with required quantities of dry and green fodder, concentrates and mineral licks under the shade. Animals on both farms were stall-fed and supplemented with concentrate feeds and mineral licks during late pregnancy and lactation. In all herds lactating cows received concentrates before each milking at the rate of 1 kg of concentrate per 2.5 kg of milk produce. Concentrates are prepared by mixing maize with wheat bran, noug cake (*Guizotia abyssinica*), salt and limestone. Hay produced from various types of annual and perennial plants of Gramineace species, namely, *Paspalum conjugatum, Digitaria ciliaris, Cyperus asculantus* and *Hyparrhenia* species are used for feeding animals.

Pregnant cows are managed separately during the trimester; they calved in well-constructed calving pens. Lactating cows are hand-milked twice daily at all farms, early in the morning (3 a.m.–4 a.m.) and late in the afternoon (3 p.m.–4 p.m.) and daily milk yield from individual animals are weighed and recorded. Newborn calves are taken away from their dams shortly after birth and allowed to receive colostrums for the first 5 days of their age and bucket-fed until weaning; they managed in individual pens. There was regular vaccination against anthrax, pasteurellosis, blackleg, foot and mouth disease, lumpy skin disease and contagious bovine pleura pneumonia. There was regular dosing and spraying against internal and external parasites.

Data collection

Data were collected from two dairy herds, Alage and Ardaita ATVET College dairy farms. Data of all cows archived over 14 years period on Alage and Ardaita dairy farm were used for the study. The data concerning reproductive performance of HF was collected for the period from 2000 to 2015 from the history sheet maintained at the farm.

Data were collected from records kept for each individual animal in a record book. Records has identification number, sex of animal, date and reason of exit, dates of birth, Dam and Sire ID number, calf ID, service date and calving dates, parity number and drying dates. From the collected information the following variables of interest were derived, i.e. age at first service (AFS) as the time from birth dates to first service, age at first calving (AFC) as the time from birth dates to first calving, days open (DO) as the interval in days between calving and conception, calving interval (CI) as the interval in days between two consecutive calving and number of services per conception (NSC) as the number of services the cow required until she conceived were studied. The compiled record cards were checked for its completeness and unclear and incomplete data were cleaned out.

Data analysis

The data were interred into Microsoft excel spread sheet and the traits (AFS, AFC, DO, CI and NSC) analysed using general linear model (GLM) procedures of SAS version 9.2 (SAS, 2008). Abortion and still birth records were removed from analysis of age at first calving. reproductive traits; AFS, AFC, DO, CI and SPC were analysed. The model used includes fixed effects of Agro ecology, season, year and parity. From the model Ardaita characterized as highland and Alage as lowland agro ecological conditions. Months of the year were classified into three seasons based on rainfall distribution; a short rainy season, which extends from March to June, a long rainy season, which extends from July to October and a dry season that extends from November to February. Only a few number of animals completed more than 5 lactations and also the estimated least square means for parity numbers 5 and greater than 5 were almost similar. Therefore all parities above 5 were pooled together in parity 5. For DO, CI and NSC the number of observation of animals that calved during 2002 and below were too small, there for all animals that calved below 2002 were pooled together in 2002. Likewise, the number of observation of animals that calved during 2014 and all animals that calved at 2014 and above this were pooled together in 2014. For AFS and AFC cows born during 2000 and 2001 was included. The following models were used to analyse reproductive traits in both farms.

Model 1: For AFS and AFC;

$$Y_{ijkl} = \mu + B_i + S_j + Y_k + e_{ijk},$$

where, $Y_{ijk} = n^{th}$ record of i^{th} agro ecology, j^{th} season of birth and k^{th} year of birth

μ = overall mean; B_i, fixed effect of i^{th} agro ecology (highland=Ardaita and lowland=Alage); S_j, fixed effect of j^{th} season of birth (long rainy, short rainy and dry season); Y_k, fixed effect of k^{th} year of birth (2000–2015 G.C); e_{ijk}, random error associated with each observation.

Model 2: For DO, CI and NSC;

$$Y_{ijkl} = \mu + B_i + S_j + Y_k + P_l + e_{ijkl},$$

where Y_{ijkl}, observation on CI, DO and NSC; μ, overall mean; B_i, fixed effect of i^{th} agro ecology (highland = Ardaita, lowland=Alage); S_j, fixed effect of j^{th} season of calving (long, short and dry season); Y_k, fixed effect of k^{th} year of calving (2000–2015); P_p, fixed effect of l^{th} parity (1, 2…5); e_{ijkl}, residual random error.

Results and Discussions

Age at first service

The overall least square mean and standard error of AFS was estimated to be 29.70 ± 0.49 months with coefficient of variation 21.5 percent (Table 1). The result found was in close agreement with the report of Shiferaw *et al.* (2003), which was AFS of 29.58 months for cross-bred dairy cows in central highland of Ethiopia. However, it

Table 1. Least square means (LSM) and standard errors (SE) of age at first service (AFS) (months) and age at first calving (AFC) (months) over the fixed effects of agro ecology, season of birth and year of birth.

Factor	*N*	AFS LSM ± SE	AFC LSM ± SE
Overall	191	29.70 ± 0.49	39.75 ± 0.53
CV (%)		21.5	17.3
Agro ecology		***	***
Highland	75	33.23 ± 0.78^{A}	42.74 ± 0.84^{A}
Lowland	116	26.17 ± 0.65^{B}	36.75 ± 0.69^{B}
Season of birth		NS	NS
long rainy	74	30.01 ± 0.76	39.97 ± 0.82
Short rainy	57	29.78 ± 0.90	39.71 ± 0.97
Dry season	60	29.30 ± 0.85	39.56 ± 0.89
Year of birth		**	*
2000	28	28.98 ± 1.26^{AB}	38.95 ± 1.36^{AB}
2001	14	25.31 ± 1.79^{B}	36.80 ± 1.87^{AB}
2002	13	29.87 ± 1.76^{AB}	42.84 ± 1.90^{AB}
2003	14	32.98 ± 1.69^{AB}	43.83 ± 1.82^{A}
2004	11	24.76 ± 1.91^{B}	34.35 ± 2.06^{B}
2005	12	28.99 ± 1.90^{AB}	38.75 ± 1.96^{AB}
2006	12	34.07 ± 1.90^{A}	43.54 ± 1.97^{AB}
2007	19	32.07 ± 1.42^{AB}	41.01 ± 1.59^{AB}
2008	19	30.03 ± 1.41^{AB}	39.03 ± 1.57^{AB}
2009	21	30.31 ± 1.35^{AB}	39.74 ± 1.49^{AB}
2010	28	29.34 ± 1.26^{AB}	38.38 ± 1.33^{AB}

Means separated by different superscript letters under the same variable in one column are significantly different ($P < 0.05$) *** = significant ($P < 0.001$), ** = significant ($P < 0.01$),* = ($P < 0.05$); NS, not significant; *N*, number of records.

is higher than 24.30 ± 8.01 months for Zebu × HF crossbred dairy cows in Jimma as reported by Duguma (2012) and 25.6 months for crossbred dairy cows in eastern lowlands of Ethiopia as reported by Mureda & Mekuriaw (2007).

The least square means and standard errors of AFS for the fixed effects of agro ecology, season of birth and year of birth are summarized below in Table 1. The result revealed that Agro ecology ($p < 0.001$) and year of birth significantly ($p < 0.01$) influenced AFS. But, season of birth did not have significant effect on AFS. The lower (26.17 ± 0.65 months) AFS was found in Alage (lowland) dairy farm, whereas higher (33.23 ± 0.78 months) values obtained in the Ardaita dairy farm (highland). This is in agreement with Lijalem, Assefa, & Sharo (2015) who found that the average age at first mating is shorter in lowland areas than highland under smallholder dairy production system in Sidama zone, Ethiopia. Even though, as the heifers reared in two different agro ecological zones and had different agro-climatic conditions and environment, the management of animals in Alage were comparatively favourable for cattle production that brought shorter AFS of HF cows. These results are an indication of the high possibility for intensive heifer rearing under better management system in the Alage ATVET College dairy farm than Ardaita ATVET college. This large difference could also have resulted from the low level of management and poor feeding of calves and heifers at the earlier stages, which consequently had reduced growth rate and delayed puberty in the highlands than lowlands. It is imperative that the feeding and management of calves and heifers must be improved to achieve low AFS performance in the future.

The non-significant effect of season of birth on AFS of HF in the current study was in agreement with previous findings reported by Melaku (2007); Lemma, Belihu, & Sheferaw (2010); Tadesse *et al.* (2010).

The significant effect of year of birth on AFS reported in this study is in agreement with the reports of Effa *et al.* (2006), Tadesse *et al.* (2010), Fekadu, Kassa, & Belihu (2010) and Menale *et al.* (2011). But, different from the report of Tadesse *et al.* (2006) for HF dairy cows in Ethiopia. The highest value of AFS recorded during 2006, whereas lowest value observed during 2001 and 2004 (Figure 2). From 2000 to 2006 the trend of AFS was inconsistence (Figure 2). Given this facts the wide variations of AFS over the years and the overall improving trend indicate influence of various aspects of the environment on the animals and more specifically management practices and the climate (Ansari-Lari *et al.*, 2009).

Age at first calving

The overall least square mean and standard error of AFC was estimated to be 39.75 ± 0.53 months with coefficient of variation 17.3 percent. The result is in close agreement with 39.2 ± 7.5 months with coefficient of variation of 19 percent for HF cows in Ethiopia as reported by Tadesse *et al.* (2010), 40.9 ± 0.33 months for HF herd in Holeta reported by Yalew, Lobago, & Goshu (2011) and 40.9 ± 6.6 months for crossbreed cows in North Shoa reported by Ayalew & Asefa (2013). The mean AFC obtained was higher than 29.3 months that was reported for Tunisian Friesian-Holstein cows reported by Ajili *et al.* (2007); 823 days (27.2 months) for HF cows in Pakistan reported by Niazi & Aleem (2003) and 988 ± 9.81 days (32.7 months) reported by Sattar *et al.* (2005). However, the result found in this study was lower than 41 ± 6 months reported for Tunisian Friesian-Holstein by Krishantan & Sinniah (2014) and 54 months reported by Banga *et al.* (2007) in Zimbabwe. The AFC was above the standard interval of 2 years expected in a well managed crossbreed cattle. The prolonged AFC of HF cows could be attributed to factors such as poor nutrition and management practices. With good nutrition it is expected that heifers would exhibit fast growth and attain higher weights at relatively younger ages (Tadesse *et al.*, 2010).

The least square means and standard errors of AFC for the fixed effects of agro ecology, season of birth and year of birth are summarized in Table 1. The result revealed that agro ecology ($p < 0.001$) and year of birth ($p < 0.05$) had significant effect on AFC of HF cows, while the effect of season of birth was not significant. HF cows kept in

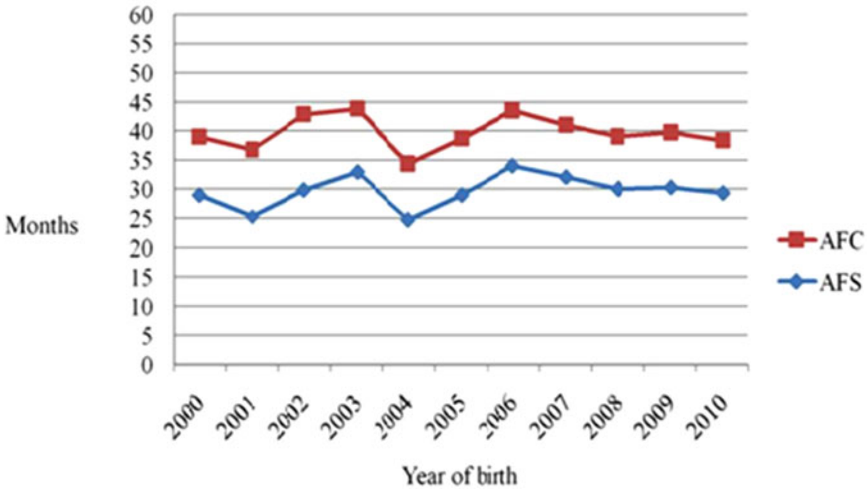

Figure 2. The trend of AFS and AFO over year of birth at Alage and Ardaita ATVET college.

the lowland (Alage) showed lower value of AFC than the cows that kept in the highland (Ardaita) of Ethiopia (Table 1). This might be an indication of comparatively better calf management system in Alage dairy farm. As the heifers were reared in two different agro ecological zones and had different agro-climate, environment and management conditions, the growth rate of heifers varied accordingly. This could result better potential of HF cattle with regard to AFC under lowland condition. Relatively, better AFS performance observed in this study was an indicative of lower value of AFC in the lowland agro ecological condition.

The non-significant effect of season of birth ($p > 0.05$) in the present study was disagreed with Chenyambuga & Mseleko (2009) in Tanzania who reported significant effect of season of birth on AFC. The significant effect of year of birth in the present study ($p < 0.05$) is in line with Tadesse *et al.* (2010) who stated that period of birth significantly ($p < 0.001$) influenced AFC of Friesian cows in Ethiopia. Besides, Bruns *et al.* (2004) stated that year of calving had a significant influence on AFC of HF cattle in Malawi. The lowest value of AFC was observed during 2004, whereas the highest value of AFC was recorded during 2003 and 2006, respectively (refer Figure 2). From 2000 to 2006 the trend of AFC was inconsistence (refer Figure. 2). In other times AFC remains constant. The lowest value of AFC in this study might be well management and better adaptation of HF breed to the prevailing tropical environment, climatic condition for heifers and heat detection when heifers attain puberty during that time.

Days open

The overall least square mean and standard error of DO of 188.11 ± 7.22 days with coefficient of variation 55.3 percent found in this study was comparable with Goshu *et al.* (2007) for DO of 177 ± 5.4 days for HF cows in Stella Private dairy farm and Shiferaw *et al.* (2003) of 185 days for crossbred dairy cows in Ethiopia. However, Tadesse *et al.* (2010) estimated lower mean DO of 148 ± 1.72 days with CV 11 percent for HF dairy cows in Ethiopia. While, the result in this study was lower than the results reported by Asimwe & Kifaro (2007) of 205 ± 2.6 days for HF in Tanzania. Such differences could have been caused by difference in environmental factors under which animals kept or management factors such as ability to detect heat signs after calving eventually influencing the number of DO.

The least square means and standard errors of DO for the fixed effects of agro ecology, season of calving, year of calving and parity are summarized in Table 2. The result showed that agro ecology ($p < 0.05$), year of calving and parity ($p < 0.001$) had significant effect, while season of calving did not have a significant effect ($p > 0.05$) on DO of HF dairy cows. The significant effects of agro ecology on DO obtained in this study are in agreement with the reports of Bayou *et al.* (2015). In the current study, HF cows which calved in the highland had shorter period of (174.59 ± 10.38 days) DO than cows, which calved in lowland (201.62 ± 7.75 days). This is due to high heat stress condition in Alage may prevent the ability of animals to come in heat. Furthermore, high ambient temperature experienced in the lowland could be attributed to factors like delayed resumption of ovarian activity after calving, longer interval to first estrus and a brief shorter duration of estrus along with its silent symptoms. Comparatively favourable environment, which can influence the ovarian activities in Ardaita dairy farm may contribute better potential of HF cows with regard to DO under highland condition than lowland condition. Fertility of cattle is also reduced due to low intensity and duration of estrus caused by reduced luteinizing hormone (LH) and estradiol secretion during thermal stress (Rensis & Scaramuzzi, 2003).

The non-significant effect of season of calving on DO is in agreement with the report of Tadesse *et al.* (2010) who

Table 2. Least square means (LSM) and standard errors (SE) of calving interval (CI) (days), days open (DO) (days) and number of service per conception (NSC) over the fixed effects of agro ecology, season of calving, year of calving and parity.

Factor	*N*	CI LSM ± SE	*N*	DO LSM ± SE	*N*	SPC LSM ± SE
Over all	383	465.76 ± 7.22	406	188.11 ± 7.22	517	1.31 ± 0.04
CV(%)		22.3		55.3		44.8
Agro ecology		NS		*		*
Highland	144	460.98 ± 10.36	153	174.59 ± 10.38^{B}	187	1.25 ± 0.05^{A}
Lowland	239	470.55 ± 7.93	253	201.62 ± 7.75^{A}	330	1.38 ± 0.04^{B}
Season of calving		NS		NS		NS
Long rainy	118	463 ± 11.26	125	185.20 ± 10.92	159	1.33 ± 0.06
Short rainy	133	466 ± 10.92	140	193.06 ± 10.87	180	1.31 ± 0.05
Dry season	132	468 ± 10.11	141	186.05 ± 10.11	178	1.30 ± 0.05
Year of calving		***		***		**
2002	14	445 ± 28.84^{CB}	13	172.43 ± 30.11^{CAB}	15	1.44 ± 0.16^{CB}
2003	24	515.48 ± 23.36^{CAB}	22	216.58 ± 24.54^{CAB}	30	1.19 ± 0.12^{D}
2004	12	534 ± 31.67^{AB}	11	234.04 ± 33.18^{CAB}	13	1.17 ± 0.17^{D}
2005	29	574 ± 20.27^{A}	27	276.27 ± 21.06^{A}	41	1.20 ± 0.10^{D}
2006	19	464 ± 24.74^{CB}	20	193.10 ± 24.41^{CAB}	25	1.41 ± 0.12^{CB}
2007	33	461 ± 18.99^{CB}	35	206.23 ± 18.56^{CAB}	44	1.62 ± 0.09^{A}
2008	21	508 ± 23.08^{CAB}	25	245.61 ± 21.47^{AB}	34	1.27 ± 0.10^{CD}
2009	33	451 ± 18.53^{CB}	32	157.58 ± 19.10^{CB}	38	1.39 ± 0.10^{CB}
2010	28	430 ± 20.17^{CB}	28	155.82 ± 20.46^{CB}	31	1.22 ± 0.11^{D}
2011	48	442 ± 15.63^{CB}	43	159.90 ± 16.95^{CB}	53	1.20 ± 0.08^{D}
2012	53	433 ± 14.93^{CB}	52	151.37 ± 15.24^{C}	55	1.19 ± 0.08^{D}
2013	57	412 ± 14.45^{C}	61	143.37 ± 14.02^{C}	69	1.29 ± 0.07^{CD}
2014	12	385 ± 30.65^{C}	37	133.08 ± 17.56^{C}	69	1.50 ± 0.07^{AB}
Parity		***		***		NS
1	144	506 ± 9.52^{A}	143	237.36 ± 9.40^{A}	184	1.30 ± 0.05
2	97	446 ± 1.20^{B}	114	172.31 ± 10.44^{B}	134	1.32 ± 0.06
3	68	471 ± 13.52^{AB}	73	190.10 ± 13.29^{B}	87	1.33 ± 0.07
4	34	444 ± 18.87^{B}	37	146.87 ± 18.47^{B}	57	1.33 ± 0.09
5	24	462 ± 17.64^{AB}	39	193.90 ± 17.94^{AB}	55	1.29 ± 0.09

Means separated by different superscript letters under the same variable in one column are significantly different ($P < 0.05$). *** = significant ($P < 0.001$), * = ($P < 0.05$); NS, not significant; *N*, number of records.

found that unlike CFSI and DO, the significant effect of season of calving on CI is not expected. The significant effect of year of calving and parity on DO obtained in this study is in agreement with Tadesse *et al.* (2010) who reported similar significant effect of period of calving and parity on DO of HF breed in Ethiopia. The significant effects of period of calving ($p < 0.001$) on DO were also reported by Asimwe & Kifaro (2007). From the current study mean DO showed significantly increasing trend for cows that were calved from 2002 to 2005 and then a decreasing trend from cows that were calved from 2008 to 2014 (Figure 2). The highest value observed in 2005, where as the lowest value recorded during 2012–2014 and remains constant from other times, which had slight significance difference (Table 2). The highest value observed might be attributed to inadequate nutrition before and after calving, poor heat detection and other management variability as a resulted of insufficient budget allocation and negligence of herd management practices.

The significant effect of parity reported in the present study is in agreement with the reports of previous authors (Mureda & Mekuriaw, 2007; Chenyambuga & Mseleko, 2009; Tadesse *et al.*, 2010; Denbarga, Woldegebriel, & Shiferaw, 2012). In contrast, Menale *et al.* (2011) found non-significant effect of parity of dam on DO. The longest DO was recorded in parity one and parity five, respectively which had statistically difference with all other parities. While, after 1st parity DO was decreased up to 4th parity, which had no significant difference (Table 2).

Calving interval

The overall mean and standard error of CI of HF found was estimated to be 465.76 ± 7.22 days with coefficient of variation 22.3 percent. It was in close agreement with the mean CI of 462.87 ± 19.48 days for HF cows in Hosanna town, Ethiopia (Kebede, 2015) and 460 ± 99 days for HF dairy cows in Sri Lanka (Herath, Sivayoganathan, & Dissanayaka, 2002), respectively. However, it was lower than the CI of imported (449 days) and local born Friesian cows (436 days) in Pakistan reported by Niazi & Aleem (2003), 459 ± 2.4 days reported by Tadesse (2001) for HF crosses in central highland of Ethiopia, 514.33 ± 23.44 days at Alage for HF cows reported by Melaku (2007). The CI in the present study is above the normal interval of 365 days expected on a commercial dairy farm. Based on the evidence obtained in this study, it appears that longer CI is mainly attributed to the result of longer DO obtained, which could be related to environmental factors, mismanagement practices like failure to detect heat, in adequate nutrition before and after calving, poor health condition, the amount of energy fed influence the percent of cows cycling. Relatively longer CI might be indicative of poor nutritional status, poor breeding management, lack of own bull and artificial insemination service, longer days open, diseases and poor management practices (Duguma *et al.*, 2012).

The least square means and standard errors of CI for the fixed effects of agro ecology, season of calving, year of calving and parity are summarized in Table 2. The result showed that year of calving and parity ($p < 0.001$) had significant effect on CI of HF dairy cattle. It appears that CI was not affected by agro ecology and season of calving ($p > 0.05$). The non-significant effect of calving season on CI is in agreement with Mekuriaw, Ayalew, & Hegde (2009) and Lemma, Belihu, & Sheferaw (2010), but Tadesse *et al.* (2010) found significant ($p > 0.001$) effect of season of calving on CI.

The significant effect of year of calving is in agreement with Tadesse *et al*. (2010) who reported similar significant effect of year of calving ($p < 0.05$) on CI of HF breed in Ethiopia. The estimates of CI showed a progressively increasing trend from the cows that were calved from 2002 to 2005 and significantly, a decreasing trend from the cows that were calved in between 2008 and 2014 remains constant during 2006 and 2007 (Figure 3). The peak value of CI recorded the cows that were calved during 2005, whereas lowest value recorded during 2013 and 2014 (Figure 3). Generally, the progressive decreasing trend of CI from the current study could be a sign of improvement in the ability of the college to manage their dairy cattle and the adaptation of the breed to the prevailing environment through time. Melaku (2007), Tadesse *et al.* (2010) and Menale *et al.* (2011) in Ethiopia and Chenyambuga & Mseleko (2009) in Tanzania found year to year difference in CI on HF dairy cattle.

Similar to the present finding, the significant effect of parity on CI were reported by Tadesse & Dessie (2003), Goshu *et al.* (2007), Mekuriaw, Ayalew, & Hegde (2009), Tadesse *et al*. (2010) and Menale *et al.* (2011) in Ethiopia. Chenyambuga & Mseleko (2009) in Tanzania reported significant effect of parity on CI. On contrary to the current finding, Mulindwa *et al.* (2006) in Uganda found that parity did not significantly ($p > 0.05$) affect CI.

The highest CI was obtained in parity one which had significant difference with other parities. The lowest CI was recorded in parity two and four (Table 2). This is due to an indicative of lower value of DO recorded during this time. The trend of CI was decreased up to parity four and then increased as the parity goes beyond parity four (Table 2). This could be associated with improvement in reproductive management and physiological maturity is attained with advanced age of cows (Tadesse *et al*., 2010). The prolonged CI for first calving has been reported to be physiologically necessary to allow animals to replenish their fat reserves depleted during lactation and this allows them to put on weight prior to the next calving (Mahadevan, 1951).

Number of service per-conception

The overall mean and standard error of NSC of pure HF cows found was estimated to be 1.31 ± 0.04 with CV 44.8 percent. The result is nearly comparable with Moges (2012) who reported that services required for each conception was 1.3, 1.5 in urban level of precision and peri urban areas of Gonder, respectively. However, the overall mean NSC obtained in this study was lower than NSC of 2.0 reported for HF dairy cattle in Nigeria (Ngodigha, Etokeren, & Mgbere, 2009) and 2.11 for HF in Pakistan (Niazi & Aleem, 2003). Furthermore, the result

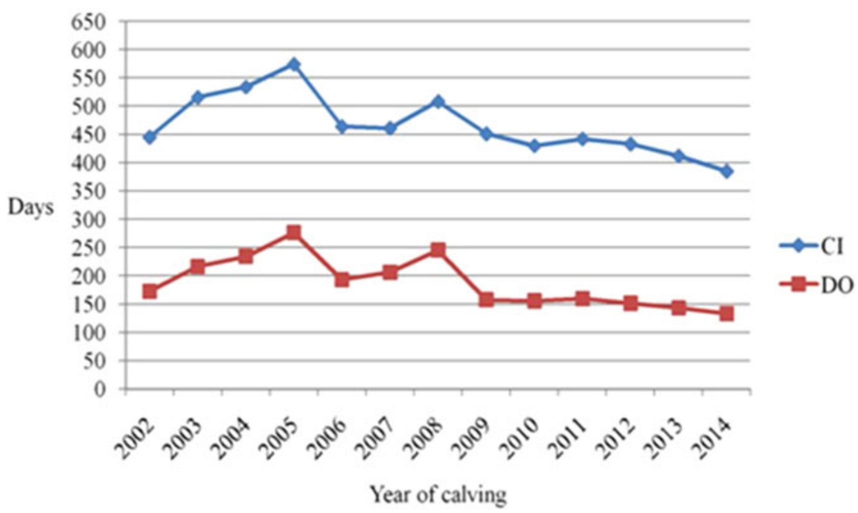

Figure 3. The trend of CI and DO over year of calving at Alage and Ardaita ATVET college.

of the present study is lower than the report of Yosef (2006) who found that NSC of 2.01 for Holstein breed in central highland of Ethiopia, Lateef (2007) who found that NSC of 3.30 for HF in Pakistan and 1.80 for HF reported by Tadesse *et al*. (2010). However, Goshu *et al.* (2007) observed that the average service per conception of 1.72 ± 0.056 for HF cows at Stella private dairy farm. The promising value of NSC suggested for HF in the current study found could be due to comparatively successful service, quality of semen, skill of the inseminator, proper time of insemination and cows related factors, management, nutrition and climate conditions may also contribute better value of NSC in the study area.

The least square means and standard errors of NSC for the fixed effects of agro ecology, season of calving, year of calving and parity are summarized in Table 2. The result revealed that Agro-ecology ($p < 0.05$) and year of calving ($p < 0.01$) had significant effect on NSC, but season of calving and parity had no significant effect ($p > 0.05$). Mean NSC was significantly higher for cows in Alage and lower for Ardaita Holstein cows. This lower value of NSC in Ardaita farm is due to the ability of HF dairy cattle to conceive successfully in the highlands than lowlands. Thermal stress prior to and immediately after artificial insemination, causes reduction in conception rate in high producing lactating cows (Ricardo *et al.*, 2004).

The non-significant effect of calving season found was agreed with the findings of Goshu *et al.* (2007) for Friesian cows in Stella private dairy farm. However, it disagreed with the findings of these authors (Tessema, Gebre-Wold, & Jayaparakash, 2003; Kebede *et al.*, 2011; Denbarga, Woldegebriel, & Shiferaw, 2012) for HF cows in Ethiopia. The non-significant effect of calving season on NSC might be associated to the zero grazing practice in the farm, which makes the effects of seasonal variation in forage developments and feed availability minimal.

Significant effect of year of calving on NSC of HF dairy cattle in the current study was in line with previous authors (Gifawosen *et al.*, 2003; Yifat *et al.*, 2009; Kebede *et al.*, 2011). But, Tolla & Demeke (2000) reported a non-significant effect of calving year. In general, the trend of NSC over year of insemination was inconsistence (Figure 4). This might be due to difference in inseminators, heat detection, AI service and semen quality over the years. Besides to this, difference observed in NSC between the study years could be related to the variation in feeding and management practices across the years.

Similar to the present finding the non-significant effect of parity on NSC was reported by Ibrahim, Abraha, & Mulugeta (2011). Besides, Goshu *et al.* (2007) and Denbarga, Woldegebriel, & Shiferaw (2012) found significant effect of parity on NSC. Generally, a good proportion of conception cases suggested that the absence of repeat breeders in the herd, non occurrences of postpartum reproductive problems, accurate heat detection skills, and efficiency of AI and level of feeding in the herd. Proper and accurate heat detection is a key to efficient reproduction and four to five checks each day to determine the onset of true standing heat gives a better idea when to inseminate. Bekele and Yilma (2003) also noted a decrease in the NSC required for cows supplemented high level of protein.

Conclusions

The mean found for AFS, AFC, CI and DO of HF cows were not satisfactory and are below the standard expected from commercial dairy farm. However, the mean obtained for SPC is the normal that expected from modern dairy

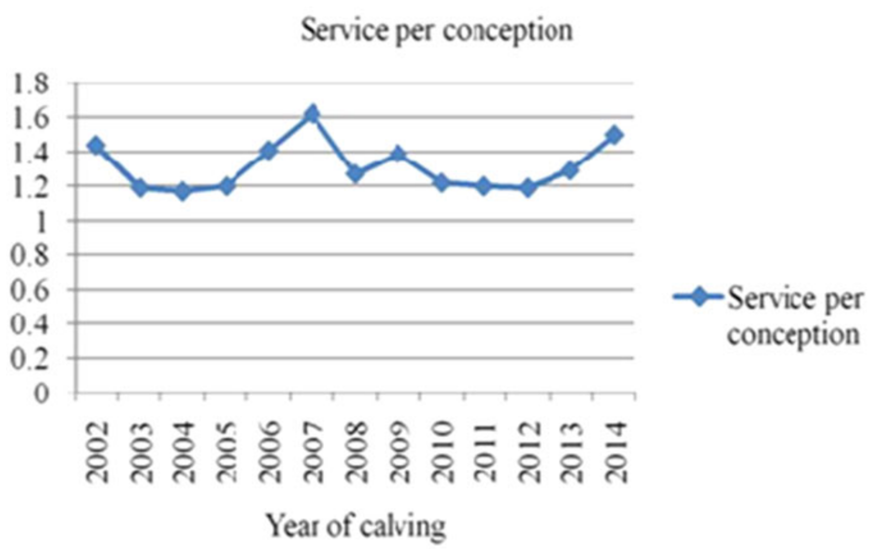

Figure 4. The trend of SPC over year of calving at Alage and Ardaita ATVET college.

farm. Agro ecology and birth years were the main source of variation for the late AFS and AFC of HF cows. Except for CI, agro ecology showed significant effect on all traits. Year of birth and year of calving had significant effect on all traits, but season of birth and season of calving showed non-significant effect on all traits. Parity had source of variation on DO and CI of HF. Indeed, the level of management and breeding practice, variation of agro eco ecology with varied management system, management differences between year of birth and year of calving might be the reasons for poor performance of dairy animals. The results therefore provided very useful information and would assist decision making particularly regarding how to improve the low reproductive performance for future production. As a result, with a better efficient heat detection, management schemes for heat stress condition in the lowland, timely insemination, postpartum reproductive health management and feeding it is possible to improve the conception rate from first service and increase the percentage of DO and CI that fall within the accepted limits.

Acknowledgements

The Authors would like to thank Alage and Ardaita ATVET College for their co-operation and offering facilities. Special thanks is offered to Bahirdar University College of Agriculture and Environmental science especially Animal Production and technology instructors for their provision of various services during teaching learning process. The Authors also thank farm attendants, farm managers, AI technicians and veterinary professionals working in dairy farms who agreed to participate in the study.

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Animal Genetic Resources, 2016, 58, 43–51. © Food and Agriculture Organization of the United Nations, 2016
doi:10.1017/S2078633615000314

Description of production system and on-farm phenotypic characterization of Central Highland and Woyto-Guji goat breeds in Ethiopia

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Summary

The study examines phenotypic characterization of Central Highland and Woyto-Guji goat breeds at Meta Robi and Konso districts of Ethiopia. Purposive and random sampling techniques were employed to select sample villages and respondent. For administration of semi-structured questionnaire and phenotypic characterization, a total of 240 households and 601 adult animals, respectively, were selected. The average goat flock size (31.25 ± 22.46) owned per household of Konso was significantly ($P < 0.01$) higher than Meta Robi (12.73 ± 8). In Konso, natural pasture was the most frequently mentioned feed source during wet season, while hay was the most important feed source during dry season. On the other hand, in Meta Robi, natural pasture was the most frequently mentioned feed source during wet and dry seasons. Coat colour type, horn shape, ear orientation, wattle and beard were found to differ highly significantly ($P < 0.001$) among the two goat breeds. Goat breed had a significant effect ($P < 0.001$) on body weight and other body measurements except pelvic width ($P > 0.05$). The least-square means of body weight, body length, height at wither, chest girth, chest width, ramp length, horn length, ear length and pelvic width of Central Highland female goats were 29.5 ± 0.2 kg, 62.2 ± 0.2 cm, 67.5 ± 0.2 cm, 72.9 ± 0.2 cm, 13.4 ± 0.1 cm, 19.7 ± 0.1 cm, 12.8 ± 0.2 cm, 14.6 ± 0.1 cm and 13.5 ± 0.1 cm, respectively. The corresponding values for Woyto-Guji female goats were 24.8 ± 0.3 kg, 57.4 ± 0.2 cm, 61.9 ± 0.2 cm, 68.3 ± 0.2 cm, 12.1 ± 0.1 cm, 17.3 ± 0.1 cm, 10 ± 0.2 cm, 13 ± 0.1 cm and 13.4 ± 0.1 cm, respectively. The observed variations in production system and morphological traits among the sample populations coupled with their adaptive traits would indeed justify the need for designing breed improvement programme for both breeds.

Keywords: *Goat breed, qualitative traits, quantitative traits*

Résumé

Cette étude est consacrée à la caractérisation phénotypique des races caprines Terres Hautes Centrales et Woyto-Guji des districts Meta Robi et Konso en Éthiopie. Les villages et les personnes enquêtées ont été choisis en suivant des techniques d'échantillonnage intentionnel et aléatoire. Pour la mise en application du questionnaire semi-structuré et pour la caractérisation phénotypique, un total de 240 ménages et de 601 animaux adultes ont été respectivement sélectionnés. La taille moyenne du troupeau de chèvres possédé par ménage a été significativement ($P < 0.01$) plus élevée au Konso (31.25 ± 22.46) qu'au Meta Robi (12.73 ± 8). Au Konso, les pâturages naturels ont été la ressource alimentaire la plus fréquemment citée pendant la saison humide alors que le foin en a été la ressource alimentaire la plus importante pendant la saison sèche. Par contre, au Meta Robi les pâturages naturels ont été la ressource alimentaire la plus fréquemment citée aussi bien en saison humide qu'en saison sèche. La couleur de la robe, la forme des cornes, l'orientation des oreilles et la présence de pendeloques et de barbiche ont différé significativement ($P < 0.001$) entre les deux races caprines. La race a eu un effet significatif ($P < 0.001$) sur le poids et sur autres mesures corporelles des chèvres, hormis la largeur pelvienne ($P > 0.05$). La moyenne des moindres carrés pour le poids corporel, la longueur du corps, la hauteur au garrot, le périmètre thoracique, la largeur de la poitrine, la longueur de la pente, la longueur des cornes, la longueur des oreilles et la largeur du bassin des femelles de race Terres Hautes Centrales a été respectivement de 29.5 ± 0.2 kg, 62.2 ± 0.2 cm, 67.5 ± 0.2 cm, 72.9 ± 0.2 cm, 13.4 ± 0.1 cm, 19.7 ± 0.1 cm, 12.8 ± 0.2 cm, 14.6 ± 0.1 cm et 13.5 ± 0.1 cm. Les valeurs correspondantes pour les femelles de race Woyto-Guji ont été respectivement de 24.8 ± 0.3 kg, 57.4 ± 0.2 cm, 61.9 ± 0.2 cm, 68.3 ± 0.2 cm, 12.1 ± 0.1 cm, 17.3 ± 0.1 cm, 10 ± 0.2 cm, 13 ± 0.1 cm et 13.4 ± 0.1 cm. Les variations observées entre les populations étudiées dans le système de production et les caractères morphologiques, avec leurs caractères adaptatifs, justifieraient certainement la nécessité de développer un programme d'amélioration pour les deux races.

Mots-clés: *race caprine, caractères qualitatifs, caractères quantitatifs*

Resumen

Este estudio aborda la caracterización fenotípica de las razas caprinas Tierras Altas del Centro y Woyto-Guji de los distritos Meta-Robi y Konso de Etiopía. Los pueblos y las personas encuestadas fueron seleccionados siguiendo técnicas de muestreo intencional y aleatorio. Para la aplicación del cuestionario semiestructurado y para la caracterización fenotípica, se seleccionaron, respectivamente, un total de 240 hogares y 601 animales adultos. El tamaño medio del rebaño de cabras poseído por hogar fue significativamente ($P <$

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0.01) mayor en Konso (31.25 ± 22.46) que en Meta-Robi (12.73 ± 8). En Konso, los pastos naturales fueron el recurso alimenticio más frecuentemente mencionado durante la estación húmeda mientras que el heno fue el recurso alimenticio más importante durante la estación seca. En cambio, en Meta-Robi, los pastos naturales fueron el recurso alimenticio más frecuentemente mencionado tanto en la estación húmeda como en la estación seca. El color de la capa, la forma de los cuernos, la orientación de las orejas y la presencia de mamellas y barba difirieron significativamente ($P < 0.001$) entre las dos razas caprinas. La raza tuvo un efecto significativo ($P < 0.001$) sobre el peso y sobre otras medidas corporales de las cabras, a excepción de la anchura pélvica ($P > 0.05$). Las medias por mínimos cuadrados para el peso corporal, la longitud del cuerpo, la altura a la cruz, la circunferencia torácica, la anchura del pecho, la longitud de la caída, la longitud de los cuernos, la longitud de las orejas y la anchura de la pelvis de las hembras de raza Tierras Altas del Centro fueron de 29.5 ± 0.2 kg, 62.2 ± 0.2, 67.5 ± 0.2, 72.9 ± 0.2, 13.4 ± 0.1, 19.7 ± 0.1, 12.8 ± 0.2, 14.6 ± 0.1 y 13.5 ± 0.1, respectivamente. Los valores correspondientes para las hembras de raza Woyto-Guji fueron de 24.8 ± 0.3 kg, 57.4 ± 0.2, 61.9 ± 0.2, 68.3 ± 0.2, 12.1 ± 0.1, 17.3 ± 0.1, 10 ± 0.2, 13 ± 0.1 y 13.4 ± 0.1 cm, respectivamente. Las variaciones observadas, entre las poblaciones muestreadas, en el sistema de producción y en los rasgos morfológicos, junto con sus caracteres adaptativos, justificarían ciertamente la necesidad de diseñar un programa de mejora para ambas razas.

Palabras clave: *raza caprina, rasgos cualitativos, rasgos cuantitativos*

Submitted 27 February 2015; accepted 22 September 2015

Introduction

The livestock population of Ethiopia is believed to be one of the largest in Africa. The report of CSA (2013) indicates that goat population of Ethiopia is roughly 24.06 million head. Goats have wide acceptance and recognition worldwide because of their multiple benefits to human; some have high reproductive rate (Peacock, 2005), ability to produce milk and meat (Tilahun and Goestseh, 2005), their milk and meat have higher digestibility and therapeutic values (Park, 1998), can inhabit a wide range of climates (Bagley, 2006) and have huge socioeconomic importance (FAO, 1999).

Understanding the diversity, distribution, basic characteristics, comparative performance and the current status of each country's animal genetic resources is essential for their efficient and sustainable use, development and conservation. Without such information, some breed populations and unique characteristics they contain may decline significantly, or be lost, before their values are recognized and measures are taken to conserve them (FAO, 2010).

Designing a suitable breeding scheme for smallholder livestock production system has remained a challenge hitherto. Until recently, livestock breeding in Ethiopia had adopted exclusively the conventional hierarchical breeding schemes (Gizaw *et al.*, 2013). The conventional hierarchical breeding schemes have several drawbacks (Gizaw and Getachew, 2009). The major shortcomings are they do not address fully the farmers' preferences under low-input systems (Gizaw *et al.*, 2011), they fail to consider the different intangible, socioeconomic and cultural roles that livestock play in each situation. This usually leads to the setting of wrong breeding objectives (Kosgey, 2004). Therefore, the objectives of this study were to describe the production system and morphological characterization of Central Highland and Woyto-Guji goat breeds of Ethiopia for designing community-based breeding strategy.

Materials and methods

Environmental setting of the study locations and goat populations

Sampling of Central Highland and Woyto-Guji breeds was done from Meta Robi and Konso districts, respectively (Figure 1). Data were collected from April to May 2013 in Meta Robi and March to April 2013 in Konso district. Meta Robi is one of the districts in the Oromia region and located 100 km northwest from the capital Addis Ababa in the West Shewa zone. The district lies in a hilly land scope at elevations from 1 200 to 2 900 m above sea level (a.s.l.) and located at 9°20′N latitude and 38°10′E longitude. The mean annual temperature and rain fall range from 23 to 31 °C and 750 to 1 100 mm, respectively. Over 95 percent of the population practices mixed crop–livestock production system (Emmenegger, 2012).

Konso is located in the southwest of Ethiopia in the Segen Area Peoples' Zone in the Southern Nations, Nationalities and People's Region. It is located 595 km away from Addis Ababa in the southwest of Ethiopia; it is located at 5°17′36″N latitude and 37°29′05″E longitude (www.google.earth.com) and lies between 600 and 2 100 m a.s.l. (Konso district agricultural office, 2008). The average total annual rainfall is 550 mm; the temperature ranges between 12 and 33 °C (Tesfaye, 2003). The annual rainfall variation is between 400 and 1 000 mm (Cheung, Senay and Singh, 2008). The production system is integrated crop–livestock system (Forch, 2003).

Data collection

Description of production system

Districts and breeds for the implementation of the mega project "Harnessing Genetic Diversity for Improving

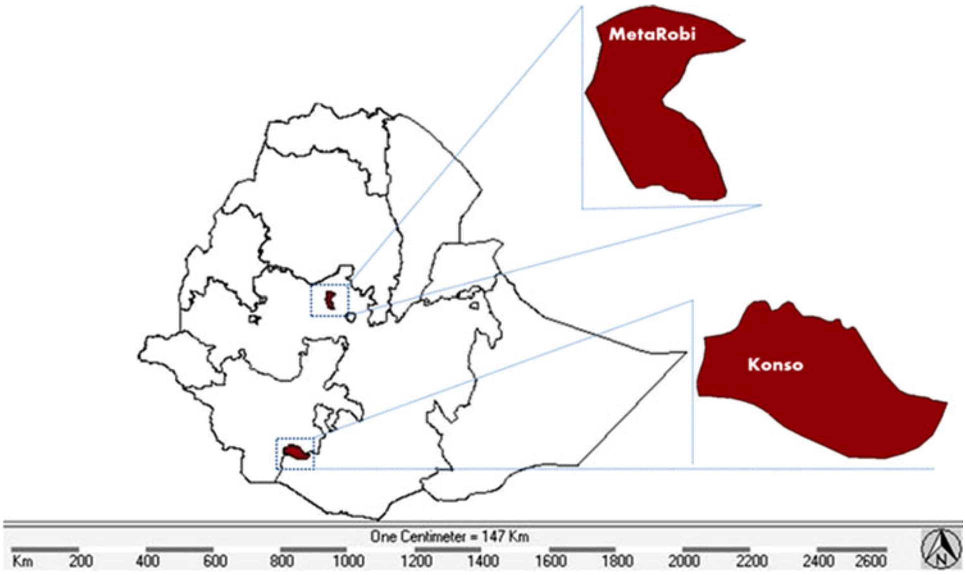

Figure 1. Map of Ethiopia and selected districts for the baseline survey and performance-monitoring studies.

Goat Productivity in Ethiopia", of which this research activity is a component, were prior identified through project scoping visits during the project design phase. Criteria considered in selecting the districts were goat population size and relative significance of contribution of goats to the livelihood of communities.

Reconnaissance visits were made to the districts of Meta Robi and Konso for selection of villages. Discussions were held with teams of researchers and experts from the partner regional Agricultural Research Centers and District Agricultural offices in the respective districts. Four villages were accordingly selected from each district by considering goat population size (based on data from the respective district agricultural offices) and relative significance contribution of goats to the livelihood of communities.

Within selected villages, list of households who owned goats and also had good experience in goat rearing were identified in reference to data at the district level agricultural offices and in consultation with village agricultural Development Agents (DAs). Then from which 120 households were selected randomly for administration of the semi-structured questionnaire.

Phenotypic characterization

A total of 601 adult animals (4PPI) (32 males and 268 females central Highland and 38 males and 263 females Woyto-guji goats) were used for linear measurements and observations on the presence or absence of key characteristic features following FAO (2011) recommendations. Linear measurements for all variables except height at wither were taken using graduated plastic measuring tape in cm with a precision of 0.5 cm, while body weight was measured using suspended spring balance in kg with a precision of 0.2 kg. Wither height measurement (cm) was taken using calibrated metal caliper. All measurements were carried out by the same person in order to avoid between individual variations and also it was done early in the morning before the animals were taken to grazing and watering.

Data management and analysis

Questionnaire data

Data collected through questionnaire were coded and entered into Statistical Package for Social Sciences (SPSS for windows, release 14.0, 2006). For data involving frequencies, descriptive statistics were in use and χ^2 or *t*-test was employed when required to test independence of categories or to assess the statistical significance. Index was calculated for ranked variable (different kinds feed sources in different seasons) in reference to its formula: Index = Sum of (3 × number of household ranked first + 2 × number of household ranked second + 1 × number of household ranked third) given for an individual reason divided by the sum of (3 × number of household ranked first + 2 × number of household ranked second + 1 × number of household ranked third) for overall reasons.

Qualitative and body measurement data

Data from the body weight, linear measurements and morphological observations for the phenotypic characterization were analysed using Statistical Analysis System (SAS Version 9.2, 2008). Qualitative data from the observations were analysed separately for both sexes within each goat breed using the frequency procedures. χ^2 test was employed to test for independence between the categorical variables. The General Linear Model procedure (PROC GLM) of SAS was used to analyse body weight

Table 1. Average flock size of the study areas.

Descriptor	Konso			Meta robi			*P*-value
	% (*N*)	Mean ± SD	Range	% (*N*)	Mean ± SD	Range	
Goat	100 (120)	31.25 ± 22.46	6–200	100 (120)	12.73 ± 8.0	4–75	**
Cattle	89.2 (107)	8.83 ± 9.83	0–70	95.8 (115)	6.35 ± 3.71	0–18	**
Sheep	86.7 (104)	7.23 ± 7.86	0–40	24.2 (29)	0.96 ± 2.12	0–13	**
Donkey	42.5 (51)	0.93 ± 1.6	0–9	54.2 (65)	1.03 ± 1.31	0–8	NS
Chicken							
Indigenous	55 (66)	4.68 ± 6.28	0–32	80 (96)	5.73 ± 6.62	0–30	NS
Exotic	1.7 (2)	0.03 ± 0.26	0–2	3.3 (4)	0.08 ± 0.45	0–4	NS
Bee hive	23.3 (28)	1.88 ± 5.89	0–50	13.3 (16)	1.08 ± 3.71	0–25	NS

**$P < 0.01$; NS, non-significant; *N*, number of households; SD, standard deviation.

and other linear body measurements. For quantitative data of adult goats the data were analysed to determine the effects of class variable (breed). The effect of class variable were expressed as least-square mean (LSM) ± SE. Due to low number of male animals in each breed all quantitative analysis were carried out using only the females.

The statistical model used was:

$$Y_{ij} = \mu + B_i + e_{ij},$$

where Y_{ij} is the observed body weight or linear measurements; μ is the overall mean; B_i is the fixed effect of the ith breed (i = Woyto-Guji, Central Highland); e_{ij} is the random error.

Results and discussion

General household characteristics

Majority of respondents (92.5 percent in Konso and 80.9 percent in Meta Robi) were more than 21 years old. Majority of the respondents (97.5 percent in Konso and 88.3 percent in Meta Robi) were male, while most of the households visited at both districts (98.3 percent in Konso and 88.3 percent in Meta Robi) were male headed. In Meta Robi, 12.4 percent of the goat keepers have attended either secondary or college education, while 41.7 percent among the remaining attended primary school. To the contrary, the proportion of respondents who attended primary schools at Konso was 18.1 percent with the remaining majority (81.9 percent) of respondents at Konso being illiterate. This may lead to a lot of bottle necks with regarding to rearing activity, veterinary care, health and hygiene, feeding strategies as well as marketing strategies. Average family size in visited households at Konso (8.52) was significantly ($P < 0.01$) higher than Meta Robi (7.34).

Livestock holding and goat flock structure

All respondents kept goat as a multispecies enterprise, while all livestock species kept were indigenous breeds. Respondents in Konso had significantly higher ($P < 0.01$) number of goat, cattle and sheep than Meta Robi. The average ± SD ownership per household of goat, cattle, sheep and donkey for Konso farmers were 31.25 ± 22.5, 8.83 ± 9.8, 7.23 ± 7.9 and 0.93 ± 1.6, respectively. The corresponding values for Meta Robi were 12.73 ± 8.0, 6.35 ± 3.71, 0.96 ± 2.12 and 1.03 ± 1.31, respectively (Table 1). FARM-Africa (1996) reported 11 goats per household for Woyto-Guji flock and ten goats per household for Central Highland flocks. On the other hand, flock size reported in Konso district was higher than the result reported in the same district by Tesfaye (2003) that is oxen, cows and sheep ownership ranged from none to four, whereas the ownership of goats reached up to eight heads of animals per household.

Table 2. Goat flock structures of the study areas.

Flock class	Konso			Meta Robi		
	Sum	Mean ± SD	%	Sum	Mean ± SD	%
Male < 6 months	338	2.96 ± 2.26	9	232	2.47 ± 1.54	13
Female < 6 months	383	3.36 ± 2.22	10	254	2.49 ± 1.45	13
Male 6 months to 1 year	399	3.91 ± 3.33	11	87	1.81 ± 1.27	10
Female 6 months to 1 year	574	4.99 ± 4.12	14	158	2.51 ± 2.68	13
Male > 1 year (Intact)	514	4.90 ± 7.43	14	111	1.82 ± 1.31	10
Female > 1 year	1 431	12.23 ± 8.63	35	616	5.4 ± 4.26	29
Castrate	116	2.52 ± 1.66	7	53	2.21 ± 1.44	12
Total	3 755		100	1 511		100

SD, standard deviation.

Table 3. Ranking feed resources of the study areas.

During dry season	Konso					Meta Robi				
	R1	R2	R3	R4	I	R1	R2	R3	R4	I
Hay	48	48	9	1	0.47	–	–	18	1	0.16
Natural pasture	53	6	1	–	0.30	107	1	–	–	0.18
Crop residue	17	17	9	1	0.18	5	5	7	3	0.07
Fallow land	1	1	3	1	0.02	2	2	15	3	0.07
Local brewery	–	–	6	2	0.02	1	1	–	1	0.05
Established pasture	1	1	–	–	0.01	1	1	–	–	0.01
Concentrates	–	–	1	–	0.003	2	2	47	18	0.1
During wet season										
Natural pasture	112	5	2	–	0.57	116	–	–	–	0.49
Crop residue	5	46	16	–	0.23	–	22	26	5	0.13
Fallow land	3	38	11	1	0.17	1	36	21	2	0.16
Local brewery	–	5	2	–	0.02	–	–	–	–	–
Hay	–	1	1	4	0.02	–	2	9	26	0.05
Established pasture	–	–	–	–	–	1	–	–	–	0.004

R1, R2, R3 and R4 = rank 1, 2, 3 and 4, respectively. *I* = index: Index = sum of (4 for rank 1 + 3 for rank 2 + 2 for rank 3 + 1 for rank 4) given for an individual reason (attribute) divided by the sum of (4 for rank 1 + 3 for rank 2 + 2 for rank 3 + 1 for rank 4) for overall reasons.

Goat flock structure across sex, age and district was summarized in Table 2. The total proportion of female and male (intact) greater than 1 year and between 6 months and 1 year is higher in Konso than Meta Robi, but the reverse is true regarding the proportion of female and male less than 6 months and castrate. The ratio of male more than 1 year and their female counterparts was about 1:3 in both the study areas. This is comparable with the inference of Endeshaw (2007) in Sidamo zone (1:4), Grum (2010) around Dire Dawa (1:5). But the result is smaller when the proportion of buck to does compared with the previous findings of Nigatu (1994) and Workneh (1992) in Ethiopia and Eritrean goats in pastoral flocks (1:19) and agro-pastoral society in South Ethiopia (1:11). Large proportion of breeding doe in both districts could imply the production of large number of kids which in turn might increase the intensity of bucks. However, the proportion of young bucks was very low in both districts. Lower proportion of young bucks compared with young does might be because of marketing of young bucks in the study areas.

Grazing practice and feed source

In Konso, natural pasture was the most frequently mentioned feed source during wet season, while hay was the most important feed source during dry season (Table 3). On the other hand, in Meta Robi, natural pasture was the most frequently mentioned feed source during wet and dry seasons. This observation is in agreement with previous studies of the country (Workneh, 1992; Grum, 2010; Feki, 2013).

Feed conservation is commonly practiced in both study areas in the form of crop residues (cereal straws) and hay from native pasture. Crop residue, grazing on fallow land, local brewery byproducts and hay were mentioned as additional feed sources during wet and dry seasons in both the study areas. The importance of this feed sources and their seasonality was also reported in Adiya Kaka (Zewdu, 2008).

Housing system

This study demonstrated that most (76.1 percent in Konso) and almost all (98.3 percent in Meta Robi) households do not mix goats with other species, but the remaining (23.9 percent in Konso and 1.7 percent in Meta Robi) mix goat with sheep during night. Majority (82.2 percent in konso and 76.7 percent in Meta Robi) of respondents kept kids separately during night. This result was in agreement with results of other studies elsewhere in Ethiopia (Grum, 2010; Biruh, 2013; Feki, 2013). In Konso, all respondents had kid's barn made with mud and wood that is tied with the house of the main flock; while in Meta Robi, kids were housed in the living house. Housing kids with adult goats as well as adult goats with large animals leads to physical injuries.

Different housing system was provided to goats by both district households. In Konso, majority (83.3 percent) of goat keepers kept their goats in yard or enclosed land in the night which all respondents made its wall with wood and its floor was mud, but it had no shed (Figure 2). The rest (16.7 percent) of respondents kept their goats in separated pen (75 percent), kept in veranda (20 percent) and in family house (5 percent) which was well roofed with grass (68.2 percent), with wood (27.3 percent) and with iron sheet (4.5 percent). Whereas as it is shown in Figure 3, in Meta Robi majority of respondents shared their family house (55 percent), kept in veranda (42 percent) and in separated pen (2.3 percent) which is well roofed (91.5 percent with grass or bush and 8.5 percent with iron sheet), its wall was majorly made with (95 percent wood and 4.2 percent grass or bush) and its floor mainly was 86.6 percent mud and 10.8 percent stone or

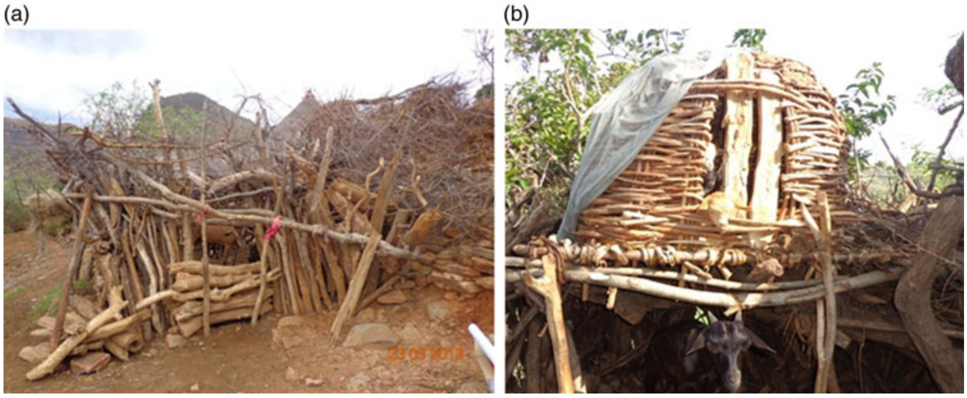

Figure 2. Common types of goat housing in Konso: separate house for kids (right) and fence enclosure or adults (left).

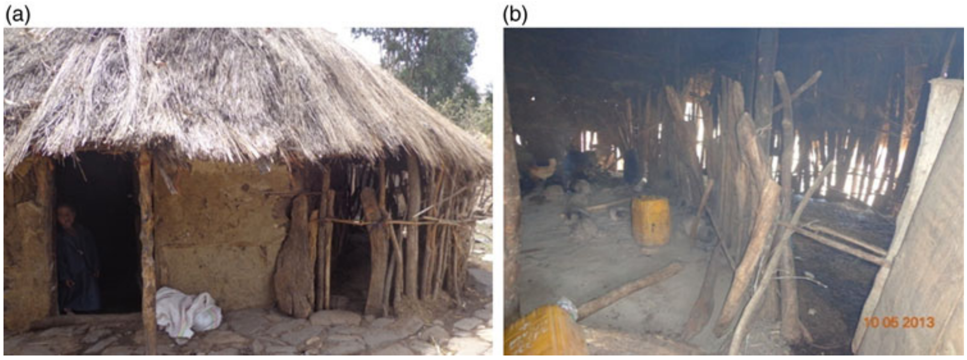

Figure 3. Common types of goat housing for adults in Meta Robi: veranda (left) and within family house (right).

bricks. This result contradicted with the report of Workneh, van Dorland and Rowlands (2004) that reported use of kraal enclosures (88 percent) during the night for pastoralists in Oromia Region. Compared with Meta Robi, Konso's farmers housing management for goats were advanced. It might be due to the number of goats per household is larger and the livelihood mostly depends on goat production, so that the contribution of goats to the societies economy is well known.

Household division of labour for management of goats

Tending goats is the responsibility of the whole family (Table 4). In both the study areas, mostly purchasing and selling (92 percent in Konso and 89 percent in Meta Robi), decision making regarding breeding (56 percent in Konso and 44 percent in Meta Robi), providing traditional and veterinary services for sick flock (77 percent in Konso

Table 4. Responsibilities for goat production activities of households in percent.

Responsible bodies	Activities						
	Selling and Purchasing	Breeding	Herding	Treating sick animals	Supplementing	Milking and making dairy products	Barn cleaning
Family in Konso							
Female ≤ 15 years	1.5	14	15	3	20	5.5	15
Female > 15 years	3	6	5	7	4	63.5	44
Males ≤ 15 years	3.5	24	41	13	34	10	28
Male > 15 years	92	56	11.5	77	16	1.5	13
Hired labour	–	–	27.5	–	26	19.5	–
Family in Meta Robi							
Female ≤ 15 years	1.5	12	23	–	28	–	36
Female > 15 years	6.5	12	6	8	17	–	64
Males ≤ 15 years	3	42	46	2	28	–	–
Male > 15 years	89	34	14	90	24	–	–
Hired labour	–	–	11	–	5	–	–

Table 5. Summary of qualitative traits of indigenous breeds (Woyto-Guji and CHL) by sex.

Character and factor level	Woyto-Guji						CHL						*P*-value
	Male		Female		Over all		Male		Female		Overall		
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	
Beard													***
Absent	13	34.2	232	88.2	245	81.4	2	6.3	153	57.1	155	51.7	
Present	25	65.8	31	11.8	56	18.6	30	93.8	115	42.9	145	48.3	
Wattle													***
Absent	38	100	261	99.2	299	99.3	26	81.3	230	85.8	256	85.3	
Present	–	–	2	0.8	2	0.7	6	18.8	38	14.2	44	14.7	
Coat colour type													***
Black	4	10.5	31	11.8	35	11.6	–	–	5	1.9	5	1.7	
White	2	5.3	15	5.7	17	5.7	–	–	5	1.9	5	1.7	
Brown	3	7.9	23	8.8	26	8.6	4	12.5	51	19	55	18.3	
Black and white	10	26.3	52	19.8	62	20.6	5	15.7	40	14.9	45	15	
Black and brown	7	18.4	78	52.9	153	50.9	8	25	42	15.7	50	16.7	
White and brown	12	31.6	64	24.3	76	25.3	15	43.8	125	46.7	140	46.7	
Horn shape													***
Straight	3	7.9	14	5.3	17	5.7	–	–	–	–	–	–	
Curved	33	86.8	249	94.7	282	93.7	5	15.6	164	61.2	169	56.3	
Spiral	2	5.3			2	0.66	27	84.4	104	38.8	131	43.7	
Ear orientation													***
Pendulous	–	–	–	–	–	–	26	81.3	224	83.6	250	83.3	
Semi-pendulous	38	100	263	100	301	100	6	18.8	44	16.4	50	16.7	

CHL, Central Highland; *N*, number of households; ***$P < 0.001$.

and 90 percent in Meta Robi) were the responsibility of adult men particularly by head of a household. As such, the preferences of the household heads (almost all of whom were male) are likely to be of particular relevance to issues of participating in a breed improvement programme.

Male children were involved mainly (41 percent for Konso and 46 percent for Meta Robi) in herding, while in Konso it was undertaken by hired male children (22 percent). Herdsman received remuneration in cash and kind (food and accommodation) for working the whole day. Women were particularly responsible with regard to milking and making dairy products (63.5 percent) only in Konso but cleaning of flock barns (34 percent for Konso and 36 percent for Meta Robi) in both the study areas. This study illustrated that women and children are involved in many goat production activities. This is in agreement with Sinn *et al.* (1999) who reported that even when men and women farm side by side throughout the day planting and harvesting crops, herding and carrying for small livestock are typically the primary responsibility of women and children (Table 5).

Phenotypic characteristics

Qualitative descriptions

The χ^2 test for assumption of equal proportion of categorical variables in Woyto-Guji and Central Highland goat breeds sample population revealed that among the variables considered in this study coat colour type, horn shape, ear orientation, wattle and beard were found significantly ($P < 0.001$) different.

The study revealed that the two breeds have a wide range of coat colours. Majority (50.9 percent) of the Woyto-Guji goats showed a mixture of black and brown with patchy

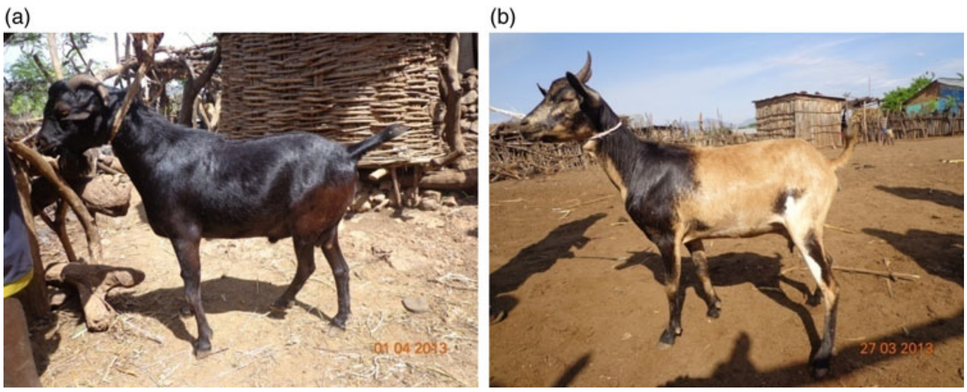

Figure 4. Male (left) and Female (right) of Weyto-Guji breed.

Figure 5. Male (left) and Female (right) of Central Highland breed.

Table 6. Least-square means and standard error (LSM ± SE) for main effect of breed on body weight and linear measurements in adult female goats.

Variables	Breed		Overall	C.V	R^2	*P*-value
	Woyto-Guji	CHL				
BW	24.8 ± 0.3	29.5 ± 0.2	27.2 ± 4.4	16.3	0.22	***
BL	57.4 ± 0.2	62.2 ± 0.2	59.8 ± 3.4	5.73	0.33	***
HW	61.9 ± 0.2	67.5 ± 0.2	64.7 ± 3.7	5.73	0.37	***
CG	68.3 ± 0.2	72.9 ± 0.2	70.6 ± 3.8	5.31	0.27	***
CW	12.1 ± 0.1	13.4 ± 0.1	12.7 ± 1.3	10.34	0.20	***
RL	17.3 ± 0.1	19.7 ± 0.1	18.5 ± 1.2	6.28	0.52	***
PW	13.4 ± 0.1	13.5 ± 0.1	13.4 ± 1.1	8.24	0.003	NS
HL	10 ± 0.2	12.8 ± 0.2	11 ± 2.5	22.72	0.37	***
EL	13 ± 0.1	14.6 ± 0.1	13.8 ± 1.2	8.72	0.31	***

BW, body weight; BL, body length; HW, height at wither; CG, chest girth; CW, chest width; RL, ramp length; PW, pelvic width; HL, horn length; EL, ear length; CHL, Central Highland; NS, non-significant; ***$P < 0.001$.

and spotted, while most of the Central Highland goats showed a mixture of white and brown coat colour with patchy and spotted. The apparent wide variation in coat colours within goat breed might be an indicative for the fact that the goat breeds has not yet undergone a strict selection procedure (Figures 4 and 5).

Overall, 81.4 percent of Woyto-Guji and 51.7 percent of Central Highland, 99.3 percent of Woyto-Guji and 85.3 percent of Central Highland, 93.7 percent of Woyto-Guji and 56.3 percent of Central Highland had beard, wattle and curved horn shape, respectively (Table 5). About 83 percent of Central Highland goats had semi-pendulous ear orientation, while all Woyto-Guji goats had pendulous. Most of the qualitative traits of Woyto-Guji goats reported in this research are in agreement with Biruh (2013) and most traits from both the goat breeds had also agreed with FARM-AFRICA (1996).

Quantitative description

The results of least-squares analysis indicated that the breed has a significant effect ($P < 0.001$) on body weight and other body measurements except pelvic width ($P > 0.05$) (Table 6). Central Highland goats had significantly ($P < 0.01$) higher values for body weight, body length, height at wither, chest girth, chest width, ramp length, horn length and ear length than Woyto-Guji. This result is in agreement with FARM-AFRICA (1996) demonstrated that the Central Highland goat types were superior on body weight, height at wither, chest girth, ear length and horn length than Woyto-Guji.

According to Devendra and Bums (1983), goats are classified as large when they weigh between 20 and 60 kg and with a height at withers above 65 cm. On this basis, the Central Highland goats observed in Meta Robi could be classified as large-sized breeds. Linear body measurements reflect breed characteristics and the management conditions under which the animals are kept. Therefore the significant ($P < 0.01$) differences in body length and height at withers observed in the indigenous goats in the different ecological zones could be attributable to the differences in genetic makeup of the animal, availability of feed resource base (in terms of quantity and quality), availability of natural grazing field and the management conditions which the animals were subjected to (Cam, Olfaz and Soydan, 2010).

Conclusion

The result revealed that the presence of wide qualitative and quantitative trait variations among two indigenous goat breeds in the various studied agro-ecological zones of Ethiopia. The goat populations in the studied areas have developed varied morphologically adaptable characteristics to be able to survive and reproduce in those environments. Among the unique qualitative traits were the type of coat colour and presence of wattle. Regarding quantitative traits such as body weight, body length, height at wither, chest girth, chest width, ramp length, horn length and ear length, Central Highland goats had significantly higher values than Woyto-Guji. The observed results could be complimented by molecular characterization and well-planned on-station reproduction and production performances evaluation for better management and conservation strategies of genetic resources for indigenous goats.

Acknowledgement

Sincere appreciation is extended to the ILRI Project "Harnessing genetic diversity for improving goat productivity in Ethiopia" that provided the finance and necessary facilitation.

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Animal Genetic Resources, 2016, 58, 53–62. © Food and Agriculture Organization of the United Nations, 2016
doi:10.1017/S2078633616000047

Morphological characterization of indigenous goats in Western Ethiopia: implication for community-based breeding programmes

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Summary

An exploratory field survey was conducted in Horro Guduru Wollega Zone, Ethiopia, to phenotypically characterize indigenous goats. Eight qualitative and fifteen quantitative traits from 612 goats were considered. All data were analysed using SAS 9.2, version 2008. The dominant coat colour types in Guduru district were black (35.29 percent), whereas in Amuru district, the dominant coat colour types were white and brown with brown dominant (18.63 percent) and brown (17.65 percent). In Horro district, the dominant coat colour types were grey (21.57 percent) and black and white with black dominant (15.69 percent). Morphometric measurements (body weight (BW), heart girth and body length) indicated that the Amuru and Horro goats were significantly ($P < 0.05$) higher than the Guduru goats. Male goats were consistently higher than female goats in all variables except pelvic width (PW). BW could be predicted from the regression equation $y = -45.22 + 1.04x$ for does and $y = -59.71 + 1.25x$ for bucks, where y and x are the BW and the heart girth, respectively. This phenotypic information serves as a basis for designing appropriate conservation and breeding strategies for goats in the study area. However, it should be substantiated with genetic characterization to guide the overall goat breeding and conservation programmes.

Keywords: *Body weight, characterization, indigenous goats, linear body measurement*

Résumé

En la zona Horro Guduru Wollega de Etiopía se llevó a cabo un estudio exploratorio de campo para la caracterización fenotípica de las cabras autóctonas. Se consideraron ocho caracteres cualitativos y quince cuantitativos en 612 cabras. Todos los datos fueron analizados con el programa SAS 9.2 (versión 2008). El color de capa dominante en el distrito de Guduru fue el negro (35,29 por ciento), mientas que en el distrito de Amuru los colores de capa dominantes fueron el blanco y el marrón, con el marrón predominando sobre el blanco (18,63 por ciento) o simplemente color marrón (17,65 por ciento). En el distrito de Horro, los colores de capa dominantes fueron el gris (21,57 por ciento) y el negro y blanco, con el negro predominando (15,69 por ciento). Las medidas morfométricas (peso corporal, circunferencia torácica y longitud corporal) fueron significativamente (P < 0,05) mayores para las cabras de Amuru y Horro que para las cabras de Guduru. Para todas las variables, excepto para la anchura de la pelvis, los machos presentaron recurrentemente valores superiores a los de las hembras. Se pudo predecir el peso corporal a partir de la ecuación de regresión y = −45,22 + 1,04x para las hembras e y = −59,71 + 1,25x para los machos, siendo "y" el peso corporal y "x" la circunferencia torácica. Esta información fenotípica sirve de base para el diseño de estrategias adecuadas para la conservación y selección de las cabras de la zona de estudio. No obstante, esta información debería ser corroborada por la caracterización genética para guiar los programas de selección y conservación de cabras en su conjunto.

Mots-clés: *poids corporel, caractérisation, chèvres autochtones, mesure corporelle linéaire*

Resumen

Dans la zone Horro Guduru Wollega de l'Éthiopie, une étude d'exploration a été menée sur le terrain pour caractériser phénotypiquement les chèvres autochtones. Huit caractères qualitatifs et quinze caractères quantitatifs ont été considérés sur 612 chèvres. Toutes les données ont été analysées avec le logiciel SAS 9.2 (version 2008). La couleur de robe dominante dans le district de Guduru a été le noir (35,29 pour cent), alors que dans le district d'Amuru les couleurs de robe dominantes ont été le blanc et le marron, avec le marron étant prédominant (18,63 pour cent), voire la seule couleur (17,65 pour cent). Dans le district de Horro, les couleurs de robe dominantes ont été le gris (21,57 pour cent) et le noir et blanc, avec le noir étant prédominant (15,69 pour cent). Pour ce qui est des mesures morphométriques (poids corporel, périmètre thoracique et longueur du corps), les chèvres des districts d'Amuru et Horro ont présenté des valeurs significativement (P < 0,05) plus élevées que celles de Guduru. Pour toutes les variables, sauf pour la largeur du bassin, les mâles ont systématiquement présenté des valeurs plus élevées que les femelles. Il a été possible de prédire le poids corporel en utilisant l'équation de régression y = −45,22 + 1,04x pour les femelles et y = −59,71 + 1,25x pour les mâles, avec y et x étant le poids corporel et le périmètre thoracique, respectivement. Cette information phénotypique sert de base pour la conception de stratégies appropriées de conservation et de sélection pour les chèvres de la zone d'étude. Toutefois, cette

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information devrait être étayée par la caractérisation génétique afin de guider les programmes de conservation et de sélection de chèvres dans son ensemble.

Palabras clave: *peso corporal, caracterización, cabras autóctonas, medida corporal lineal*

Submitted 5 July 2015; accepted 12 February 2016

Introduction

Ethiopia is endowed with varied ecological zones and possesses diverse animal genetic resources (Janke, 1983; Workneh, 1992; Alemayehu, 1993; Nigatu, 1994; FARM-Africa, 1996; IBC, 2004; Getnet *et al.*, 2005). There is a long history of trade with Arab countries across the Red Sea, with Sudan in the West, Kenya in the south and Somalia in south and southeast. The waves of this trade and physical movement of people and animals have influenced the genetic makeup of domestic livestock, including goats of Ethiopia (Janke, 1983; Workneh, 1992; Alemayehu, 1993; Nigatu, 1994; FARM-Africa, 1996; IBC, 2004; Getnet *et al.*, 2005). According to CSA (2013) there are about 24.06 million goats in Ethiopia, of which, about 71.06 percent are females and 28.94 percent are males. With respect to breed, almost all of the goats are indigenous breeds, which account about 99.99 percent (CSA, 2013). Characterization of existing goat genetic resources is very important for breed improvement and to design appropriate breeding programme for breeds that have not been adequately characterized either phenotypically and/or genetically (Mwacharo *et al.*, 2006). Characterization is essential in breed identification and classification, and the first step of it is assessing variation of morphological traits (Delgado *et al.*, 2001). In Ethiopia, phenotypic characterization done by FARM – Africa long ago in 1996 has shown the presence of 14 goat types and that survey was the first step in breed characterization of Ethiopian goats. On the contrary, genetic characterization done by Alemu (2004) revealed that the presence of only eight distinctively different breed types in Ethiopia.

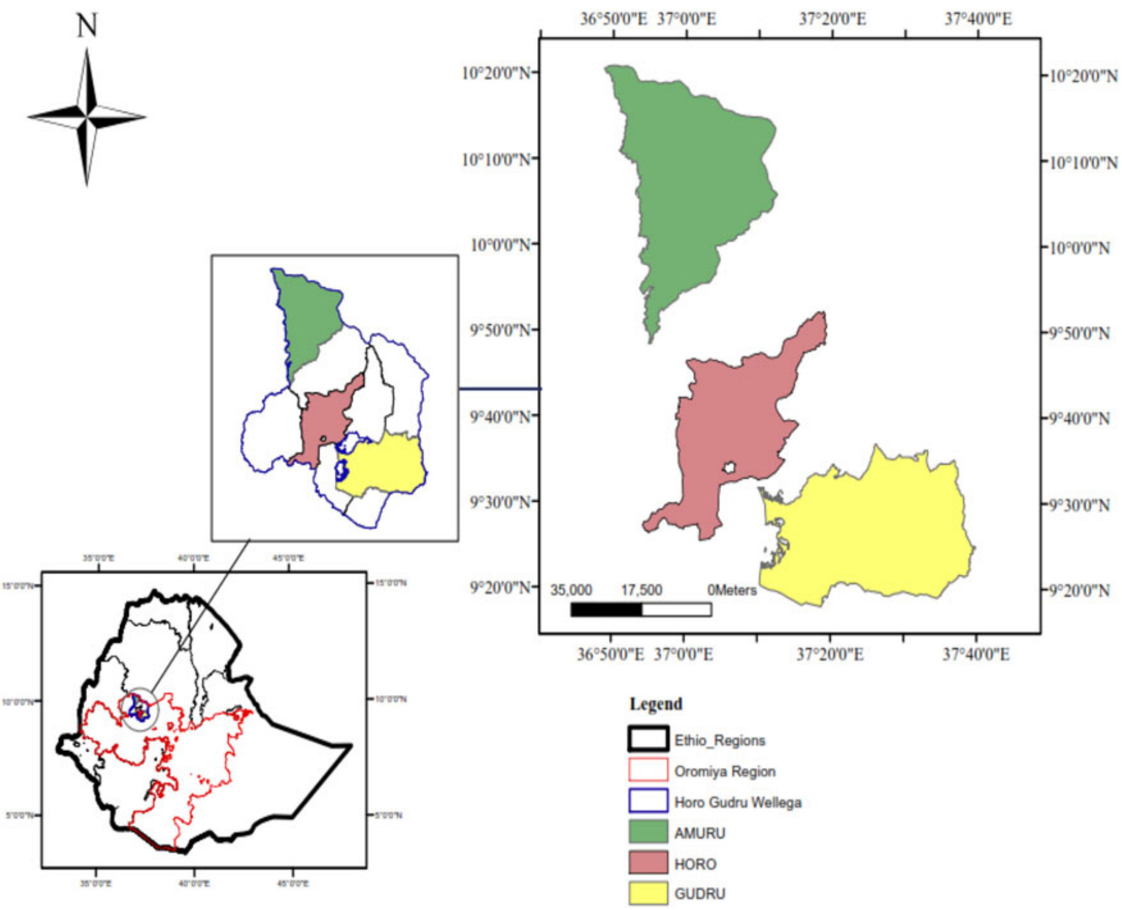

Figure 1. Map of the study area.

Figure 2. Adult indigenous breeding buck (left) and doe (right) in Guduru district.

Horro Guduru Wollega Zone is one of the geographically well-known pocket areas in the western highlands of Ethiopia and is a home for many phenotypically unique livestock species, which are nationally and internationally recognized. Some of the well-known and phenotypically unique livestock species in this area include the Horro cattle (Mekonnen *et al*., 2012), Horro sheep (Zewdu, 2008) and more recently unique livestock species such as Horro horses (Kefena *et al.*, 2012) and Horro chicken (Nigussie, 2011). Interestingly, any casual observer can note that the goat population inhabiting in this unique agro-ecology is phenotypically unique from any other goat populations explored in other parts of the country. However, there is no empirical evidence to substantiate this hypothesis. Therefore, the objective of this study is to phenotypically characterize the indigenous goats in this unique agro-ecological zone of Western Ethiopia and suggest sustainable breeding and conservation programmes to be adopted in the future.

Materials and methods

Description of study area

This study was conducted in three districts (Guduru, Horro and Amuru) of Horro Guduru Wollega zone, Western Ethiopia (Figure 1). Horro Guduru Wollega zone is found in the Western part of Ethiopia, 310 km west of Addis Ababa, the capital city of the country and the capital of the zone found 64 km to the North West of the main road from Addis to Nekemte. Horro Guduru Wollega zone is located between 09°29′N and 37°26′E, at an altitude of approximately 2296 m a.s.l, with a uni-modal rainfall ranging between 1200 and 1800 mm (Olana, 2006). The rainy season occurs from April to mid-October where maximum rain is received in months of June, July and August. Maximum temperature of 23–27 °C are reached from January to March, and minimum temperature of 7–15 °C are normal from October to November (CSA, 2006).

Sampling techniques and sample size determination

From nine districts of the zone, three sample districts were selected purposively based on the presence of relatively large goat population. From each district, three Kebeles (Peasant Associations) were selected because of the relatively large goat population. Sample goats from three kebeles were taken by using simple random sampling method.

The sample size was determined by the formula for phenotypic characterization of livestock for simple random sample (FAO, 2012) as follows.

$$n = (z/m)^2 p(1 - p), \tag{1}$$

where z is the z value (e.g. 1.96 for 95 percent confidence level); m is the margin of error, and p is the estimated value for the proportion of the sample that will respond a given way to a survey question.

Based on the above formula, 612 goats (204/district and 68/kebeles) which had one and above pair of permanent incisor (1PPI) were used for body measurements and qualitative trait descriptions. Pregnant females and castrated males were not included in sample goats to avoid inaccuracy for body weight (BW) and linear body measurements (LBMs). Based on FAO (2012), from the total sample size, 10 percent of goats were males, whereas the other 90 percent were females.

Methods of data collection

All data were recorded based on breed morphological characteristics descriptor list of FAO (2012) for phenotypic characterization of goat. Data forheart girth (HG), body length (BL), wither height (WH), rump height (RH), chest depth (CD), shoulder width (SW), pelvic width (PW), ear length (EL), rump length (RL), rump width (RW), horn length (HoL), cannon bone length (CBL),

Table 1. Qualitative traits of indigenous goats in Horro Guduru Wollega zone by sex and district.

Traits and attributes	**District**								
	Guduru			**Amuru**			**Horro**		
	F *N* **(percent)**	**M** *N* **(percent)**	**Total** *N* **(percent)**	**F** *N* **(percent)**	**M** *N* **(percent)**	**Total** *N* **(percent)**	**F** *N* **(percent)**	**M** *N* **(percent)**	**Total** *N* **(percent)**
Coat colour pattern									
Plain	140 (74.47)	14 (87.50)	154 (75.49)	113 (64.94)	16 (53.33)	129 (63.24)	106 (56.99)	8 (44.44)	114 (55.88)
Pied	22 (11.70)	2 (12.50)	24 (11.76)	54 (31.03)	12 (40.00)	66 (32.35)	56 (30.11)	5 (27.78)	61 (29.90)
Patchy	26 (13.83)	–	26 (12.75)	7 (4.02)	2 (6.67)	9 (4.41)	17 (9.14)	5 (27.78)	22 (10.78)
Shaded	–	–	–	–	–	–	7 (3.76)	–	7 (3.43)
χ^2 *value*	*49.401**								
Coat colour type									
White	10 (5.32)	–	10 (4.90)	23 (13.22)	4 (13.33)	27 (13.24)	15 (8.06)	–	15 (7.35)
Black	63 (33.51)	9 (56.25)	72 (35.29)	12 (6.90)	2 (6.67)	14 (6.86)	24 (12.90)	2 (11.11)	26 (12.75)
Brown	30 (15.96)	1 (6.25)	31 (15.20)	35 (20.11)	2 (6.67)	36 (17.65)	24 (12.90)	–	24 (11.76)
Light brown	–	–	–	1 (0.57)	–	1 (0.49)	–	–	–
Grey	35 (18.62)	4 (25.00)	39 (19.12)	23 (13.22)	4 (13.33)	27 (13.24)	39 (20.97)	5 (27.78)	44 (21.57)
Red	2 (1.06)	–	2 (0.98)	22 (12.64)	5 (16.67)	27 (13.24)	5 (2.69)	1 (5.56)	6 (2.94)
Roan	26 (13.83)	–	26 (12.75)	5 (2.87)	2 (6.67)	7 (3.43)	7 (3.76)	2 (11.11)	9 (4.41)
Red + White	1 (0.53)	–	1 (0.49)	6 (3.45)	–	6 (2.94)	4 (2.15)	–	4 (1.96)
Black + White	14 (7.45)	2 (12.50)	16 (7.84)	18 (10.34)	3 (10.00)	21 (10.29)	29 (15.59)	3 (16.67)	32 (15.69)
White + Brown	7 (3.72)	–	7 (3.43)	30 (17.24)	8 (26.67)	38 (18.63)	18 (9.68)	1 (5.56)	19 (9.31)
Black + Brown	–	–	–	–	–	–	21 (11.29)	4 (22.22)	25 (12.25)
χ^2 *value*									*196.25**
Horn presence									
Present	171 (90.96)	16 (100.0)	187 (91.67)	155 (89.08)	22 (73.33)	177 (86.76)	140 (75.27)	11 (61.11)	151 (74.02)
Absent	17 (9.04)	–	17 (8.33)	19 (10.92)	8 (26.67)	27 (13.24)	46 (24.73)	7 (38.89)	53 (25.98)
χ^2 *value*							*25.38**		
Horn shape									
Straight	51 (29.82)	7 (43.75)	58 (31.02)	55 (35.26)	13 (61.90)	68 (38.42)	69 (49.64)	5 (45.45)	74 (49.00)
Curved	32 (18.71)	6 (37.50)	38 (20.32)	36 (23.08)	5 (23.81)	41 (23.16)	9 (6.47)	1 (9.09)	10 (6.62)
U shaped	88 (51.46)	3 (18.75)	91 (48.66)	57 (36.54)	3 (14.29)	60 (33.89)	61 (43.88)	5 (45.45)	66 (43.71)
Spiral	–	–	–	8 (5.13)	–	8 (4.52)	–	–	–
χ^2 *value*							*41.58**		
Horn orientation									
Backward	16 (9.36)	4 (25.00)	20 (10.69)	56 (35.90)	9 (42.86)	65 (36.72)	57 (41.01)	5 (45.45)	62 (41.06)
Upward	155 (90.64)	12 (75.00)	167 (89.31)	100 (64.10)	12 (57.14)	112 (63.28)	82 (58.99)	6 (54.55)	88 (58.28)
χ^2 *value*							*46.99**		
Ear Orientation									
Dropy	89 (47.34)	7 (43.75)	96 (47.06)	58 (33.33)	7 (23.33)	65 (31.86)	59 (31.72)	8 (44.44)	67 (32.84)
Lateral	86 (45.74)	9 (56.25)	95 (46.57)	113 (64.94)	21 (70.00)	134 (65.69)	84 (45.16)	9 (50.00)	93 (45.59)
Forward	13 (6.91)	–	13 (6.37)	3 (1.72)	2 (6.67)	5 (2.45)	38 (20.43)	–	38 (18.63)
Backward	–	–	–	–	–	–	5 (2.69)	1 (5.56)	6 (2.94)
χ^2 *value*							*61.63**		

Beard									
Absent	101 (53.72)	4 (25.00)	105 (51.47)	96 (55.17)	5 (16.67)	101 (49.51)	98 (52.69)	2 (11.11)	100 (49.02)
Present	87 (46.28)	12 (75.00)	99 (48.53)	78 (44.83)	25 (83.33)	103 (50.49)	88 (47.31)	16 (88.89)	104 (50.98)
χ^2 value	*0.27^{NS}*								
Ruff									
Absent	132 (70.21)	7 (43.75)	139 (68.14)	119 (68.39)	1 (3.33)	120 (58.82)	66 (35.48)	–	66 (32.35)
Present	56 (29.79)	9 (56.25)	65 (31.86)	55 (31.61)	29 (96.67)	84 (41.18)	120 (64.52)	18 (100.0)	138 (67.65)
χ^2 value	*56.47**								

*=$P<0.05$ for both sexes across district, NS = $P>0.05$

cannon bone circumference (CBC) and head length (HL)) were measured using tailors measuring tape while BW was measured using suspended spring balance. Data were collected for qualitative traits (coat colour pattern, coat colour type, horn presence, horn shape, horn orientation, ear orientation, ruff presence and bear presence) through visual observations.

Statistical data analysis

All data gathered during the study period were coded and recorded. Different types of statistical analysis were used based on the nature of the data. Both qualitative and quantitative data were analysed using Statistical Analysis System (SAS version 9.2, 2008). Chi-square (χ^2) test was carried out to assess the statistical significance among categorical variables (qualitative variables). Multiple correspondence analyses were carried out for variables which were significant by χ^2 and fisher test to show the association among different categories of qualitative traits. General linear model procedure (PROC GLM) of SAS was used to identify district, sex and age group effect on quantitative traits. Tukey's comparison test was used to compare the sub factor brought significant difference.

$$y_{ijk} = \mu + A_i + S_j + D_k + e_{ijk},$$

where

y_{ijk}, the observation of BW and LBMs excluding scrotum circumference in the ith age group, jth sex and kth district; μ, overall mean; A_i, the effect of ith age group (i = one pair of permanent incisors, two pairs of permanent incisors, three pairs of permanent incisors, four pairs of permanent incisors); S_j is the effect of jth sex (j = female, male); D_k is the effect of kth district (k = Guduru, Amuru, Horro), and e_{ijk} is the random residual error.

To estimate BW from LBMs, the maximum adjusted R^2 method of SAS (2008) was used. The small sample size of bucks in this study may decrease the accuracy of the result if separate age groups were used. Thus, instead of using separate equation for different age groups, it seems logical to pool age groups of male and female goats separately. Stepwise procedures were used to screen out the best fitted model. In the first step, all LBMs were entered together into the model for each sex and a group of variables having the maximum adjusted R^2 and minimum MSE were selected. In addition, Akaike's information criteria (AIC), the mallow's parameters C (P), Schwarz Bayesian criteria (SBC) were considered. In the second step, the variables which are selected by maximum adjusted R^2 and minimum MSE were entered together into the model to find the best fitted regression equation.

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + e_j,$$

where y is the dependent variable (BW); β_0, the intercept; $X_1, \ldots, X_n$, the independent variables (HG, BL, WH, RH, CD, PW, SW, EL, HoL, RL, RW, HL, CBC, CBL); $\beta 1 \ldots,$

Figure 3. Adult indigenous breeding buck (left) and doe (right) in Amuru district.

Figure 4. Adult indigenous breeding buck (left) and doe (right) in Horro district.

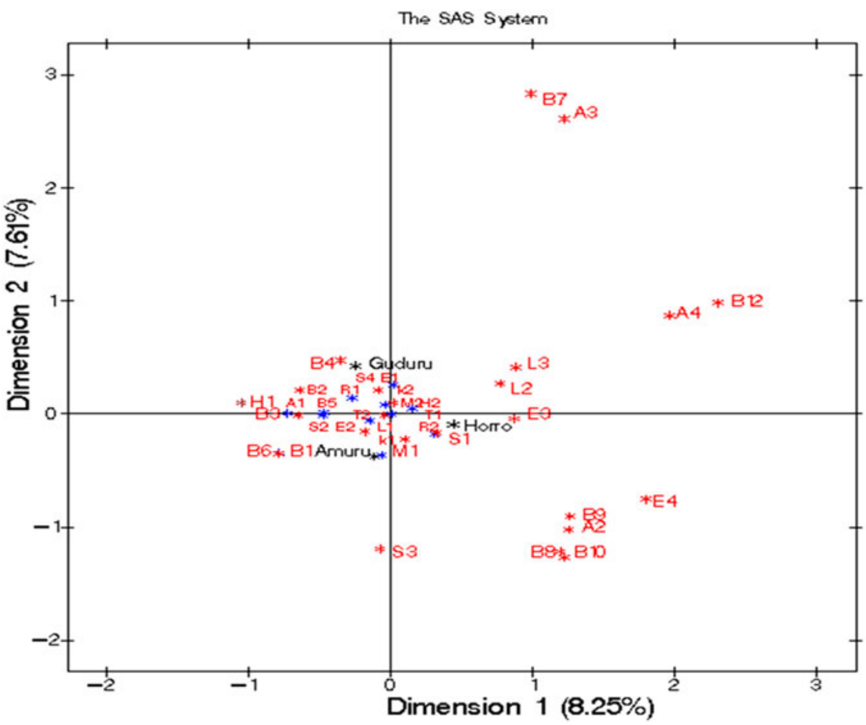

Figure 5. Bi-dimensional plot showing the associations among the categories of the different morphological variables.

Table 2. Least-squares means for body quantitative traits as affected by district, sex and age group.

Effects and levels	BW LSM ± SE	HG LSM ± SE	BL LSM ± SE	WH LSM ± SE	RH LSM ± SE	EL LSM ± SE	HoL LSM ± SE	PW LSM ± SE	SW LSM ± SE
Overall	28.7 ± 0.3	70.8 ± 0.2	56.9 ± 0.2	67.2 ± 0.2	69.4 ± 0.2	14.9 ± 0.1	10.2 ± 0.2	6.4 ± 0.0	14.6 ± 0.0
CV percent	15.6	6.7	6.2	5.0	4.8	10.1	24.8	10.8	11.0
R^2	0.5	0.4	0.5	0.4	0.3	0.2	0.5	0.5	0.2
District	*	*	*	*	*	*	*	*	*
Guduru	27.9 ± 0.4^{b}	70.5 ± 0.4^{b}	57.0 ± 0.3^{b}	66.8 ± 0.3^{b}	69.0 ± 0.3^{b}	14.0 ± 0.1^{c}	10.2 ± 0.3^{c}	5.5 ± 0.1^{c}	14.6 ± 0.2^{b}
Amuru	30.5 ± 0.4^{a}	71.8 ± 0.4^{a}	58.4 ± 0.3^{a}	68.5 ± 0.3^{b}	70.7 ± 0.3^{a}	15.0 ± 0.1^{b}	10.8 ± 0.3^{b}	6.4 ± 0.1^{a}	14.5 ± 0.2^{b}
Horro	31.3 ± 0.4^{a}	72.3 ± 0.4^{a}	58.6 ± 0.3^{a}	68.7 ± 0.3^{a}	70.8 ± 0.3^{a}	15.7 ± 0.1^{a}	11.8 ± 0.3^{a}	6.0 ± 0.1^{b}	15.5 ± 0.2^{a}
Sex	*	*	*	*	*	ns	*	*	*
Female	26.8 ± 0.2^{b}	69.2 ± 0.2^{b}	55.5 ± 0.1^{b}	66.2 ± 0.1^{b}	68.6 ± 0.1^{b}	14.9 ± 0.1	9.1 ± 0.1^{b}	6.4 ± 0.0^{a}	14.3 ± 0.1^{b}
Male	33.0 ± 0.6^{a}	73.8 ± 0.7^{a}	60.5 ± 0.5^{a}	69.7 ± 0.4^{a}	71.9 ± 0.4^{a}	14.9 ± 0.2	12.8 ± 0.4^{a}	5.5 ± 0.1^{b}	15.4 ± 0.2^{a}
Age group	*	*	*	*	*	*	*	*	ns
1PPI	23.8 ± 0.4^{d}	67.2 ± 0.4^{c}	53.2 ± 0.3^{d}	65.2 ± 0.3^{c}	67.2 ± 0.3^{c}	14.4 ± 0.1^{b}	9.2 ± 0.3^{b}	5.4 ± 0.1^{d}	14.4 ± 0.2
2PPI	27.1 ± 0.6^{c}	69.7 ± 0.7^{b}	56.3 ± 0.5^{c}	66.3 ± 0.5^{c}	68.9 ± 0.5^{b}	15.0 ± 0.2^{a}	11.4 ± 0.6^{a}	5.7 ± 0.1^{c}	15.0 ± 0.2
3PPI	32.4 ± 0.7^{b}	73.6 ± 0.7^{a}	60.0 ± 0.5^{b}	69.2 ± 0.5^{b}	71.6 ± 0.5^{a}	15.1 ± 0.2^{a}	11.2 ± 0.5^{a}	6.2 ± 0.1^{b}	15.0 ± 0.3
4PPI	36.4 ± 0.8^{a}	75.6 ± 0.8^{a}	62.5 ± 0.6^{a}	71.2 ± 0.6^{a}	73.1 ± 0.5^{a}	15.2 ± 0.2^{a}	11.1 ± 0.8^{a}	6.6 ± 0.1^{a}	14.9 ± 0.3

Overall	14.7 ± 0.1	30.0 ± 0.1	14.3 ± 0.1	13.4 ± 0.1	13.9 ± 0.0	9.3 ± 0.0
CV percent	8.3	6.7	8.9	9.7	6.3	10.9
R^2	0.3	0.4	0.3	0.3	0.1	0.1
District	*	*	*	*	*	*
Guduru	14.1 ± 0.1^{c}	29.4 ± 0.1^{b}	13.6 ± 0.1^{b}	13.0 ± 0.1^{c}	13.8 ± 0.0^{b}	9.8 ± 0.1^{a}
Amuru	14.8 ± 0.1^{b}	30.8 ± 0.1^{a}	13.8 ± 0.1^{b}	13.4 ± 0.1^{b}	13.9 ± 0.0^{b}	9.1 ± 0.1^{b}
Horro	15.6 ± 0.1^{a}	30.9 ± 0.1^{a}	15.2 ± 0.1^{a}	14.0 ± 0.1^{a}	14.2 ± 0.0^{a}	9.5 ± 0.1^{c}
Sex	*	*	ns	*	*	*
Female	14.5 ± 0.1^{b}	29.3 ± 0.1^{b}	14.1 ± 0.0	13.2 ± 0.0^{b}	13.8 ± 0.0^{b}	9.1 ± 0.1^{b}
Male	15.2 ± 0.2^{a}	31.4 ± 0.2^{a}	14.3 ± 0.1	13.7 ± 0.1^{a}	14.2 ± 0.1^{a}	9.8 ± 0.1^{a}
Age group	*	*	*	*	ns	ns
1PPI	14.3 ± 0.1^{c}	28.7 ± 0.1^{d}	13.8 ± 0.1^{b}	14.0 ± 0.2^{a}	13.9 ± 0.0	9.3 ± 0.1
2PPI	14.7 ± 0.1^{bc}	29.9 ± 0.3^{c}	14.1 ± 0.1^{ab}	14.2 ± 0.2^{a}	14.1 ± 0.1	9.7 ± 0.2
3PPI	14.8 ± 0.2^{b}	30.9 ± 0.3^{b}	14.6 ± 0.2^{a}	13.2 ± 0.1^{b}	13.9 ± 0.1	9.5 ± 0.2
4PPI	15.5 ± 0.2^{a}	31.9 ± 0.3^{a}	14.5 ± 0.2^{a}	12.5 ± 0.1^{c}	14.1 ± 0.1	9.5 ± 0.2

^{a,b,c,d}Means on the same column with different superscripts within the specified sex, district and dentition group are significantly different ($P < 0.05$); ns, non-significant ($P > 0.05$).
BW, body weight; BL, body length; HG, heart girth; WH, wither height; RH, rump height; HoL, horn length; EL, ear length; PW, pelvic width; SW, shoulder width; 1PPI, 1 pair of permanent incisors; 2PPI, 2 pair of permanent incisors; 3PPI, 3 pairs of permanent incisors; 4PPI, 4 pairs of permanent incisors; HL, head length; CD, chest depth; RW, rump width; RL, rump length; CBL, cannon bone length; CBC, cannon bone circumference; 1PPI, 1 pair of permanent incisors; 2PPI, 2 pair of permanent incisors; 3PPI, 3 pairs of permanent incisors; 4PPI, 4 pairs of permanent incisors; NA, not applicable.

βn, the regression coefficients of the variables $X_1, \ldots, Xn$; and ej, the residual random error.

Results

Qualitative traits

The most observed coat colour pattern in the study districts was plain (75.49 percent in Guduru, 63.24 percent in Amuru and 55.88 percent in Horro). Pied coat colour pattern was relatively observed in Amuru (32.35 percent) and Horro (29.90 percent) district goats than in Guduru district goats (11.76 percent). Eleven types of coat colours were identified in sample districts. From those colours, black and grey accounted 35.29 and 19.12 percent, respectively, in Guduru district goats (Figure 2 and Table 1), whereas in Amuru district goats, the dominant coat colour types were white and brown with brown dominant (18.63 percent) and brown (17.65 percent) (Figure 3 and Table 1). In Horro district goats, grey (21.57 percent) and black and white with black dominant (15.69 percent) were the frequently occurred coat colour types (Figure 4 and Table 1).

Majority of goats (91.67 percent in Guduru, 86.76 percent in Amuru and 74.02 percent in Horro) were horned and most of these horned goats had upward horn orientation. In Guduru, 48.66 percent of goats had U shaped horn; however, in Amuru and Horro, 38.42 and 49.00 percent of goats had straight horn shape, respectively. Most of goats in sample districts had Lateral and dropy ear orientations. Most of qualitative traits were not influenced by sex except beard and ruff presence which was mostly expressed in male goats.

Multiple correspondence analysis

The common qualitative characteristics among goats of the three districts were investigated by a multiple correspondence analysis. A bi-dimensional graph representing the associations among different categories of qualitative traits

Table 3. Correlation coefficients among BW and linear measurements ofHorro Guduru Wollega goats (values above the diagonal are for males and below the diagonal are for females).

	HoL	EL	HL	CD	SW	HG	CBL	CBC	RW	RL	PW	BL	WH	RH	BW
HoL		0.21^{ns}	0.24^{ns}	0.30*	0.21^{ns}	0.30*	0.23^{ns}	0.09^{ns}	0.30*	0.08^{ns}	0.18^{ns}	0.23^{ns}	0.45*	0.39*	0.31*
EL	0.13*		0.58*	0.48*	0.56*	0.38*	0.58*	−0.05^{ns}	0.43*	0.38*	0.39*	.52*	0.34*	0.35*	0.35*
HL	0.31*	0.41*		0.57*	0.59*	0.44*	0.53*	0.01^{ns}	0.46*	0.55*	.31*	0.52*	0.53*	0.56*	0.38*
CD	0.32*	0.37*	0.47*		0.52*	0.81*	0.60*	0.19^{ns}	0.75*	0.46*	0.64*	0.78*	0.82*	0.82*	0.79*
SW	0.18*	0.31*	0.47*	0.38*		0.43*	0.62*	0.15^{ns}	0.55*	0.44*	.27*	0.45*	0.44*	0.49*	0.32*
HG	0.35*	0.23*	0.40*	0.60*	0.38*		0.40*	0.24^{ns}	0.73*	0.49*	0.58*	0.77*	0.83*	0.83*	0.89*
CBL	0.06^{ns}	0.28*	0.20*	0.35*	0.32*	0.25*		0.10^{ns}	0.47*	0.40*	0.33*	0.37*	0.49*	0.49*	0.38*
CBC	0.08*	0.09*	0.13*	0.30*	0.40*	0.29*	0.36*		0.26^{ns}	0.20^{ns}	−0.04^{ns}	−0.01^{ns}	0.16^{ns}	0.15^{ns}	0.18^{ns}
RW	0.33*	0.19*	0.35*	0.43*	0.39*	0.50*	0.25*	0.23*		0.48*	0.54*	0.73*	0.73*	0.73*	0.66*
RL	0.17*	0.34*	0.44*	0.43*	0.34*	01.37*	0.36*	0.20*	0.27*		0.25*	0.46*	0.44*	0.50*	0.40*
PW	0.24*	0.25*	0.35*	0.42*	0.25*	0.51*	0.21*	0.08^{ns}	0.49*	0.28*		0.68*	0.65*	0.64*	0.59*
BL	0.37*	0.29*	0.43*	0.68*	0.39*	0.70*	0.33*	0.37*	0.57*	0.42*	0.56*		0.72*	0.77*	0.82*
WH	0.32*	0.30*	0.39*	0.62*	0.31*	0.65*	0.37*	0.22*	0.53*	0.40*	0.53*	0.70*		0.97*	0.81*
RH	0.31*	0.34*	0.40*	0.62*	0.35*	0.62*	0.39*	0.25*	0.51*	0.40*	0.51*	0.66*	0.92*		0.81*
BW	0.41*	0.35*	0.46*	0.71*	0.44*	0.81*	0.32*	0.30*	0.55*	0.46*	0.58*	0.75*	0.72*	0.69*	

ns, non-significant ($P > 0.05$); *, significant at 0.05 level.
BL, body length; HG, heart girth; WH, wither height; RH, rump height; RW, rump width; RL, rump length; CD, chest depth; PW, pelvic width; SW, shoulder width; HL, head length; CBL, cannon bone length; CBC, cannon bone length; HoL, horn length; EL, ear length; BW, body weight; SC, scrotal circumference.

is presented in Figure 5. The interpretation is based on points found in approximately the same direction from the origin and in approximately the same region of the space. Around 16 percent of the total variation is explained by the two dimensions (8.25 percent by the first and 7.61 percent by the second dimensions). On the dimensions identified, goat populations from the three districts shared some common characteristics. This might be due to the geographic proximity and possible gene flow among the three districts.

Quantitative traits

Sex effect: The least-squares means for the effect of sex had significant effect ($P < 0.05$) on all quantitative traits except EL and RL. This indicates that, sexual dimorphism was observed in most of quantitative traits. Male goats were consistently higher than female goats in all quantitative traits except PW, which is slightly higher for female goats (Table 2).

District effect: District had significant effect ($p < 0.05$) on all quantitative variables. For all quantitative traits except for CBC the Amuru and Horro district goats were significantly ($P < 0.05$) higher than Guduru goats (Table 2). At the scope of this study, it is very difficult to link this difference to any genetic background and it might be due to different management practice of the farmers.

Age effect: BW and all body measurements were significantly affected ($P < 0.05$) by age group except CBL. BW, CD, heart girth, BL, RH, EL and HL were increased as the age increased from the youngest (1PPI) to the oldest (4PPI) age group (Table 2). Though, is very difficult to generalize, a good observation from this study was that CBL hardly increases after goats replace their milk incisor teeth to permanent incisor teeth.

Correlation between BW and LBMs

BW was significantly ($P < 0.05$) correlated with all quantitative traits of both male and female goats except CBC in male (Table 3). The quantitative traits in both male and female goat population depicted weak to strong correlations and most of the traits had significant ($P < 0.05$) and positive associations.

In male goats, heart girth had strong positive correlation ($r = 0.89$) with BW followed by BL ($r = 0.82$), WH ($r = 0.81$), RH ($r = 0.81$). In female goats heart girth had also strong positive correlation with BW ($r = 0.81$).The strong positive and significant correlation between BW and heart girth suggested that these variables could provide a good estimate in predicting live BW of goats.

Prediction of BW from LBMs

Heart girth was the first variable to explain more variation than other variables in both female (79 percent) and male (82 percent) goats of Horro Guduru Wollega. As shown in Table 4, adjusted R^2 did not always increase as new

Table 4. Multiple regression analysis of live BW on different body measurements of female and male goats in the study area in all age groups

For female goats Model	**b0**	**Parameters**							**Adj. R^2**	***C* (*P*)**	**AIC**	**MSE**	**SBC**
		b1	***b2***	***b3***	***b4***	***b5***	***b6***	***b7***					
HG	−45.22	1.04							0.79	135.4	1148.6	2.86	1157.2
HG + BL	−46.78	0.78	0.36						0.82	48.30	1073.7	2.67	1086.6
HG + BL + CD	−48.22	0.71	0.31	0.30					0.83	27.71	1054.3	2.62	1071.5
HG + BL + CD + RL	−49.53	0.69	0.30	0.27	0.28				0.83	17.56	1044.5	2.59	1065.9
HG + BL + CD + RL + EL	−50.74	0.69	0.30	0.23	0.23	0.20			0.83	12.26	1039.2	2.58	1065.0
HG + BL + CD + RL + EL + WH	−53.20	0.66	0.28	0.22	0.22	0.19	0.12		0.83	8.13	1035.0	2.57	1065.2
HG + BL + CD + RL + EL + WH + HoL	−52.33	0.64	0.27	0.21	0.22	0.19	0.11	0.05	0.83	6.62	1033.5	2.56	1067.9
For male goats													
HG	−59.71	1.25							0.82	28.54	152.56	3.30	156.85
HG + BL	−62.03	0.87	0.50						0.86	12.20	139.75	2.96	146.18
HG + BL + RW	−62.55	1.03	0.52	−0.9					0.87	6.32	134.13	2.81	142.70
HG + BL + RW + EL	−60.07	1.02	0.59	−0.9	−0.4				0.88	4.45	132.03	2.75	142.74
HG + BL + RW + EL + CD	−62.44	0.93	0.54	−1.1	−0.5	0.50			0.88	3.19	130.35	2.69	143.21

HG, heart girth; BL, body length; CD, chest depth; RL, rump length; EL, ear length; WH, wither height; HoL, horn length, R^2, coefficient of determination, AIC, Alkaike's information criteria; *C* (*P*), the mallow's parameters; SBC, Schwarz Bayesian criteria; MSE, mean square error.

variable was added to the model but the addition of new variables decreased the *C* (*P*), AIC, MSE and SBC with little or no influence on the adjusted R^2. It should be noted that when new variable was added to the model, *C* (*P*), AIC, MSE and SBC usually decreased but addition of unnecessary variable to the model might increase the error. Thus the result of the multiple regression analysis indicated that the addition of other LBMs to heart girth did not result in significant increase in adjusted R^2, but it significantly improved the accuracy of prediction by decreasing the error even though the amount was small. Therefore, at farmers level, where weighing scales are not available and complex formula is not understandable, BW could be predicted from the regression equation $y = -45.22 + 1.04x$ for does and $y = -59.71 + 1.25x$ for bucks, where y and x are the BW and heart girth, respectively.

Discussions

In this study, the physical description of goats for most of qualitative traits was different from the results of different authors in different areas (Farm-Africa, 1996; Mahilet, 2012; Gebreyesus *et al.*, 2013; Abegaz *et al.*, 2013). Around 65 percent of goats in the study area had plain coat colour pattern with 18.30 percent black and 17.97 percent grey. The result showed that the phenotypic characteristics of traits like coat colour pattern and coat colour type for Horro Guduru Wollega goats represent totally different population of goat than the previous report of Farm-Africa (1996) who reported that 51 percent of western highland goats had plain coat colour pattern with 42 percent white and 42 percent fawn. Most (84.15 percent) of goats in the study area were horned goats. Similarly, Farm-Africa (1996) reported that, 86 percent of goats in western highland of Ethiopia had horn.

The significant performance difference ($P < 0.05$) of male goats and female goats for most of quantitative traits shown in this study was in line with the results of Mahilet (2012) in Eastern Hararghe and Gebreyesus *et al.*, (2013) in Diredewa. The overall average BW of male (33 kg) and female (26.8 kg) indigenous goats in the study area differed from the average BW of Hararghe goats as reported by Mahilet (2012) with 27 and 24 kg for males and females, respectively. A significant effect of age is also reported by Mekasha (2007) who shows the effect of age on BW and other body measurements in different goat breeds of Ethiopia. The strong positive and significant correlation between BW and heart girth reported in this study strongly agrees with the results of Gebreyesus *et al.*, (2013) and Mahilet (2012).

Conclusions

This study provided that goat population in Horro district was significantly different from goat population in Guduru district in both qualitative and quantitative characters. In addition, goat population in the study area had shown different phenotypic characteristics with relative to western highland breed. At the scope of this study, it is very difficult to link this difference to any genetic background and it might be due to different management practice of the farmers. Further genetic study may fully describe this unique goat population and should be focus of future research.

Acknowledgements

We greatly acknowledge the Haramaya University for financial support. Special thanks go to farmers who spared their animals for this study and developmental agents for their keen support during field data collection.

Statement of interest

The authors declare that there is no conflict of interest involved in this study.

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Animal Genetic Resources, 2016, 58, 63–71. © Food and Agriculture Organization of the United Nations, 2016
doi:10.1017/S2078633615000338

Effect of inbreeding and individual increase in inbreeding on growth in Nilagiri and Sandyno breeds of sheep

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Summary

Individual increase in inbreeding coefficients (ΔF_i) has been recommended as an alternate measure of inbreeding. It can account for the differences in pedigree knowledge of individual animals and avoids overestimation due to increased number of known generations. The effect of inbreeding (F) and equivalent inbreeding (EF) calculated from ΔF_i, on growth traits were studied in Nilagiri and Sandyno flocks of sheep. The study was based on data maintained at the Sheep Breeding Research Station, Sandynallah. The pedigree information and equivalent number of generations were less in Sandyno compared with Nilagiri sheep. The average F and EF for the Nilagiri population were 2.17 and 2.44, respectively and the corresponding values for Sandyno sheep were 0.83 and 0.84, respectively. The trend of inbreeding over years in both the populations indicated that EF was higher during earlier generations when pedigree information was shallow. Among the significant effects of inbreeding, the depression in growth per 1 percent increase in inbreeding ranged from 0.04 kg in weaning weight to 0.10 kg in yearling weight. In general, more traits were affected by inbreeding in Nilagiri sheep, in which greater regression of growth traits was noticed with F compared with EF. Higher values of EF than F in earlier generations in both the populations indicate that EF avoided the potential overestimation of inbreeding coefficient during recent generations. In the Sandyno population, the magnitude of depression noticed among growth traits with significant effects of inbreeding was higher. The differences in response to F and EF noticed in the two populations and possible causes for the trait wise differences in response to F and EF are appropriately discussed.

Keywords: *Sheep, inbreeding, individual increase in inbreeding, depression, growth*

Résumé

L'accroissement individuel des coefficients de consanguinité (ΔF_i) a été recommandé comme une mesure alternative de la consanguinité du fait qu'il tient compte des différences dans la connaissance que l'on a de la généalogie des animaux individuels et vu qu'il évite la surestimation résultant d'un plus grand nombre de générations connues. L'effet de la consanguinité (F) et de la consanguinité équivalente (EF), celles-ci calculées à partir de ΔF_i, sur les paramètres de croissance a été étudié dans des troupeaux de moutons Nilagiri et Sandyno. L'étude s'est basée sur des données conservées à la Station de Recherche pour l'Amélioration des Ovins (Sandynallah). La généalogie était moins connue et le nombre équivalent de générations était plus faible pour les moutons Sandyno que pour les moutons Nilagiri. Les valeurs moyennes de F et de EF pour la population Nilagiri ont été respectivement de 2,17 et 2,44, avec les valeurs correspondantes pour les moutons Sandyno ayant été respectivement de 0,83 et 0,84. Dans les deux populations, l'évolution suivie au cours des années par la consanguinité montre que EF était plus élevée dans les premières générations, pour lesquelles moins d'information sur la généalogie était disponible. Parmi les effets significatifs de la consanguinité, la dépression de la croissance a varié de 0,04 kg pour le poids au sevrage à 0,10 kg pour le poids à un an de vie pour chaque 1 pour cent d'augmentation de la consanguinité. En général, les caractères affectés par la consanguinité ont été plus nombreux chez les moutons Nilagiri, pour lesquels une plus forte dépression des paramètres de croissance avec F qu'avec EF a été observée. L'obtention de valeurs plus élevées pour EF que pour F dans les premières générations des deux populations révèle que EF a évité la possible surestimation du coefficient de consanguinité dans les générations récentes. La dépression de la croissance par l'effet significatif de la consanguinité a été plus forte dans la population Sandyno. Les différences décelées dans les deux populations pour ce qui est de la réponse à F et à EF et les causes possibles de ces différences sont dûment discutées.

Mots-clés: *moutons, consanguinité, accroissement individuel de la consanguinité, dépression, croissance*

Resumen

El incremento individual de los coeficientes de endogamia (ΔF_i) ha sido recomendado como una medida alternativa de la endogamia ya que tiene en cuenta las diferencias en el conocimiento que se tiene de la genealogía de animales individuales y evita la sobreestimación

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debida a un mayor número de generaciones conocidas. El efecto de la endogamia (F) y de la endogamia equivalente (EF), calculadas a partir de ΔF_i, sobre los parámetros de crecimiento fue estudiado en rebaños de ovejas Nilagiri y Sandyno. El estudio se basó en datos conservados en la Estación de Investigación para la Mejora del Ganado Ovino (Sandynallah). Se dispuso de menos información sobre la genealogía y el número equivalente de generaciones fue menor para las ovejas Sandyno que para las ovejas Nilagiri. Los valores medios de F y EF para la población Nilagiri fueron de 2,17 y 2,44, respectivamente, y los valores correspondientes para las ovejas Sandyno fueron de 0,83 y 0,84, respectivamente. En ambas poblaciones, la evolución seguida a lo largo de los años por la endogamia hizo ver que EF era mayor en las generaciones tempranas, en las que la información sobre la genealogía fue escasa. Entre los efectos significativos de la endogamia, la depresión del crecimiento varió de 0,04 kg en el peso al destete a 0,10 kg en el peso al año de vida por cada 1 por ciento de incremento de la endogamia. En general, fueron más los caracteres que se vieron afectados por la endogamia en las ovejas Nilagiri, en las cuales se observó una mayor depresión de los parámetros de crecimiento con F que con EF. La detección de mayores valores para EF que para F en generaciones tempranas de ambas poblaciones indica que EF evitó la posible sobreestimación del coeficiente de endogamia en generaciones recientes. La depresión detectada en parámetros de crecimiento por un efecto significativo de la endogamia fue mayor en la población Sandyno. Se discuten debidamente las diferencias advertidas en las dos poblaciones en la respuesta a F y EF y las posibles causas de estas diferencias.

Palabras clave: *ovejas, endogamia, incremento individual de la endogamia, depresión, crecimiento*

Submitted 15 March 2015; accepted 22 September 2015

Introduction

Nilagiri sheep, native to the Nilagiri hills of Tamil Nadu (Acharya, 1982) is known for its adaptability to high altitude, low input system of rearing and dual utility (fine wool and meat). Sandyno sheep (Iyue, 1993; Bhatia and Arora, 2005) is a synthetic breed developed from Nilagiri sheep. The demand for wool in the region is less and the selling price doesn't even match the cost of shearing. Hence, these animals are primarily maintained for meat and therefore, the growth traits are economically important in both these sheep breeds.

Intensive use of small numbers of sires and dams, due to selection and closed nature of flocks can lead to an increase in inbreeding and reduction in genetic variability within livestock populations. Decreased performance in traits related to production, reproduction and health due to inbreeding have been reported in sheep by many authors (Lamberson and Thomas, 1984; Ercanbrack and Knight, 1991; Boujenane and Chami, 1997; Mandal *et al.*, 2002; Casellas *et al.*, 2009; Pedrosa *et al.*, 2010; Zadeh, 2012). This decrease is called inbreeding depression, which is more pronounced in traits related to fitness (Falconer and Mackay, 1996). Review of earlier studies on inbreeding in sheep indicates presence and absence of such a depressive effect for growth traits (Lamberson and Thomas, 1984). A meta-analysis by Leroy (2014) provides general result on inbreeding impact on growth traits. Both, Nilagiri and Sandyno sheep have been maintained as closed flocks under purebreeding for over 25 years and hence, depression due to inbreeding in these flocks is very much a possibility.

Most of the previous studies on the effect of inbreeding were on the influence of the traditional inbreeding coefficient (F; Wright, 1931) on different growth traits (Lamberson and Thomas, 1984; Leroy, 2014). However, F is not linear over generations and can lead to varying conclusions depending on the pedigree depth (Falconer and Mackay, 1996; Gonzalez-Recio, de Maturana and Gutierrez, 2007). Pedigree or genealogical information could influence the inference drawn on the same level of inbreeding. An alternative measure called individual increase in inbreeding (ΔF_i) (Gonzalez-Recio, de Maturana and Gutierrez, 2007; Gutiérrez *et al.*, 2008) adjusts for the variation in depth of pedigree. This approach not only directly accounts for differences in pedigree knowledge and completeness at the individual level, but also indirectly for the effects of mating policy, drift, overlap of generations, selection, migration and different contributions from a different number of ancestors as a consequence of their reflection in the pedigree of each individual, in the analysed population (Gutiérrez *et al.*, 2008).

The objective of the present study was to evaluate the effect of inbreeding on growth in the Nilagiri and Sandyno populations. The traditional F and the equivalent inbreeding (EF), calculated from ΔF_i, had their effects estimated on different growth traits in these two populations.

Materials and methods

Data and flock

Pedigree information available from 1965 to 2012 on Nilagiri and Sandyno sheep (Table 1) maintained at the Sheep Breeding Research Station, Sandynallah were utilized for the study. In 1986–87, a few Nilagiri animals were introduced from farmers' flock. Since then, the flock has been maintained as a closed herd for more than 25 years. The breed composition and formation of the Sandyno breed of sheep is presented in Table 2. They were developed by crossbreeding the local Nilagiri breed with Stavropol Merino and Rambouillet sheep. The crossbreds with 75 and 62.5 percent exotic inheritance were merged into a single group of Nilagiri synthetic, called Sandyno. The pedigree information of Sandyno animals were recorded up to the founding purebred parents.

Table 1. Pedigree information for Nilagiri and Sandyno sheep populations.

Parameter	Nilagiri	Sandyno
Number of animals	5 051	9 921
Number of founders (Base population)	759	2 018
Number of animals with both parents known	4 292	7 903
Number of sires	309	458
Number of dams	966	1 344

Growth data available from 1992 to 2012 was used for the analysis of effect of inbreeding on different growth traits.

The system of management was semi–intensive with concentrate at the rate of 150 g/animal/day fed in addition to grazing. Based on the climatic conditions, lambing was planned for two seasons in a year. The main lambing season was from February to March and remaining animals lambed during the period from September to October. Individual selection based on 6 months body weight was practiced.

Inbreeding

The inbreeding coefficient (F), defined as the proportion of loci carrying alleles that are identical by descent from a common ancestor was calculated (Wright, 1931). Coefficients of individual increase in inbreeding were calculated as per Gutierrez, Cervantes and Goyache (2009). For each animal (i), the individual increase in inbreeding (ΔF_i) was computed as follows:

$$\Delta F_i = 1 - \sqrt[\mathrm{EqG}_i - 1]{1 - F_i}$$

where, "EqG$_i$" is the equivalent complete generation for individual "i" calculated as

$$\mathrm{EqG}_i = \frac{1}{2}^n$$

where "n" is the number of generations separating the individual from each known ancestor (1 = parents, 2 = grandparents, and so on), and the sum being computed across all known ancestors of "i" (Maignel, Boichard and Verrier, 1996). Equivalent inbreeding coefficients (EF) were obtained as a product of ΔF_i and average equivalent number of generations for the pedigree (Panetto *et al.*, 2010).

Table 2. Formation of the Sandyno sheep.

Generation	Mating type	Progeny (level of inheritance)
F_1-First generation	M × N	MN (50% exotic)
F_2-Second generation	M × MN	M_2N (75% exotic)
F_3-Third generation	M_2N × MN	5 MN (62.5% exotic)

Merging of genetic groups with 62.5 and 75 percent exotic inheritance to form Sandyno breed.
M, Exotic Stavropol Merino/Rambouillet; N, Nilagiri.

Individual inbreeding coefficients, number of equivalent complete generations, percentages of known ancestors by generation and individual increase in inbreeding coefficients were computed using ENDOG version 4.8 (Gutierrez and Goyache, 2005).

Analysis

Growth traits analysed in this study were weight at birth (BW), 3 (WW), 6 (6W), 9 (9W), 12 (YW) and 18 (18W) months of age and pre and post-weaning average daily gain (ADG). Weaning was practiced at 90 days of age and post-weaning period was up to 1 year of age. Separate analyses were done for F and EF in both the breeds by fitting a general linear model including different fixed effects. The various fixed effects included were contemporary groups (CG) of lambs born during a particular year and season, the age of dam at lambing with six levels (<2 years, 3 years, 4 years, 5 years, 6 years and >6 years), litter size at birth (single, twins and triplets), sex of lamb and inbreeding. The effect of inbreeding (individual and ewe) was first included as a fixed covariate of inbreeding coefficients (F and EF). Then, both these inbreeding parameters for individual alone were included as a fixed class with five levels (0, up to 3.125, >3.125 up to 6.25, >6.25 up to 12.5 and >12.5 percent) to understand the influence of level of inbreeding on growth. All analyses were carried using SAS.

Results and discussion

Table 3 presents the results of pedigree analysis in Nilagiri and Sandyno populations. Previous studies have

Table 3. Population parameters from pedigree analysis of Nilagiri and Sandyno sheep populations.

Parameter	Nilagiri	Sandyno
Generation interval (years)		
Father – Son	2.49	2.56
Father – Daughter	2.64	3.01
Mother – Son	4.16	4.52
Mother – Daughter	4.12	4.48
Overall	3.36	3.73
Inbreeding coefficient (F (%))		
Mean	2.17	0.83
Min	0.00	0.00
Max	33.59	25.81
Proportion inbred (%)	100.00	95.00
Individual increase in inbreeding (ΔF_i (%))		
Mean	0.65	0.33
Min	0.00	0.00
Max	14.75	12.70
Equivalent no. of generations (EqG$_i$)	3.75	2.52
Equivalent inbreeding coefficient (EF (%))		
Mean	2.44	0.84
Min	0.00	0.00
Max	55.12	32.00

demonstrated that the completeness of pedigree information has an effect on the estimates for F within a breed (Lutaaya *et al.*, 1999; Cassell, Adamec, and Pearson, 2003). The value of EqG_i and percent ancestral knowledge gives an indication of pedigree depth in a population. In the present study, EqG_i for the Nilagiri and Sandyno sheep were 3.75 and 2.52, respectively. The details of pedigree analysis for the Nilagiri population have been reported earlier (Venkataramanan *et al.*, 2013). EqG_i of 2.26 reported for Santa Ines sheep was slightly lower than those found in the present study (Pedrosa *et al.*, 2010). Comparatively higher EqG_i of 4.95 for Bharat Merino sheep was reported by Gowane *et al.* (2013).

The percent ancestral knowledge for the first and fifth parental generations (first parental generation, fathers; second parental generation, grandfathers; and so on) in Nilagiri sheep were 88 and 36 percent, respectively, and corresponding values for Sandyno sheep were 81 and 21 percent, respectively (Figure 1). Gowane *et al.* (2013) observed 91 and 58 percent ancestral knowledge for the first and fifth parental generations, respectively, in their study on Bharat Merino sheep. In the present study, among the Nilagiri and Sandyno populations, Sandyno was lower in ancestral knowledge as well as EqG_i.

The average F and EF for the Nilagiri population were 2.17 and 2.44, respectively (Table 3). The Sandyno population was less inbred with F and EF values of 0.83 and 0.84, respectively. This could be due to the breeding programme involved in the formation of the Sandyno breed (Table 2). Several genetic groups with varying levels of exotic inheritance were maintained separate and finally the groups with 75 and 62.5 percent exotic inheritance were merged to form the breed.

The mean ΔF_i as a proportion of F was 30 percent (Table 2) in the Nilagiri population compared with 40 percent in Sandyno. Thus the magnitude of difference narrowed down in the Sandyno population, where individual increase in inbreeding adjusts for differences in pedigree depth. The regular inbreeding coefficient, F increases from generation to generation in a non-linear fashion (Gonzalez-Recio, de Maturana and Gutierrez, 2007). The individual F values are again non-linearly dependent on the pedigree depth of each individual. The differences in pedigree depth could lead to different conclusions concerning inbreeding depression, as noted by Smith, Cassel and Pearson (1998), Cassell, Adamec and Pearson (2003), and Gonzalez-Recio, de Maturana and Gutierrez (2007). The equivalent inbreeding coefficient, EF is a function of individual increase in inbreeding, ΔF_i which take into account the equivalent number of generation, EqG_i. The use of ΔF_i, adjusted for pedigree depth of the individual permits the distinction between two animals with the same inbreeding, but with differences in the number of generations in which this level of inbreeding had occurred (Gonzalez-Recio, de Maturana and Gutierrez, 2007; Gutiérrez *et al.*, 2008; Panetto *et al.*, 2010).

The trend of mean F and EF over years is presented in Figure 2. In both the populations, the line for F surpasses that of EF in the later years, after 2003. The higher values of F could be due to greater depth in ancestral knowledge during later generations. Since EF adjusts for the differences in pedigree, it is high for the earlier periods when pedigree knowledge is sparse. The individual inbreeding rate used for calculating EF avoided potential overestimation in the recent generations attributed to increased numbers of known generations (Gonzalez-Recio, de Maturana and Gutierrez, 2007; Panetto *et al.*, 2010).

Even though substantial inbreeding has occurred in Nilagiri and to some extent in Sandyno, the values are below critical levels. Other studies have shown that inbreeding levels higher than 10 percent could lead to inbreeding depression based economic losses (Lamberson and Thomas, 1984; Ercanbrack and Knight, 1991; Wiener, Lee and Woolliams, 1992; Boujenane and Chami, 1997; Norberg and Sorensen, 2007). In spite of higher proportion of inbred animals in Nilagiri (increase from 0 to 100 percent in the 15th generation) and

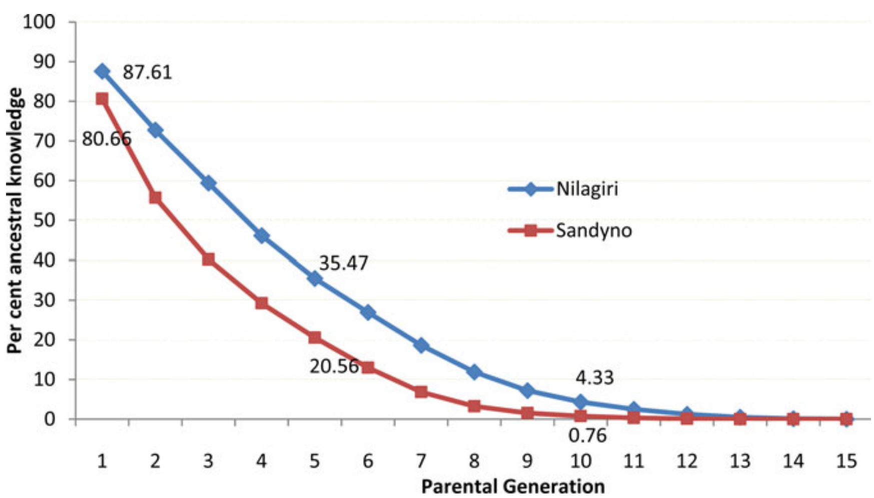

Figure 1. Percent ancestral knowledge in Nilagiri and Sandyno sheep populations.

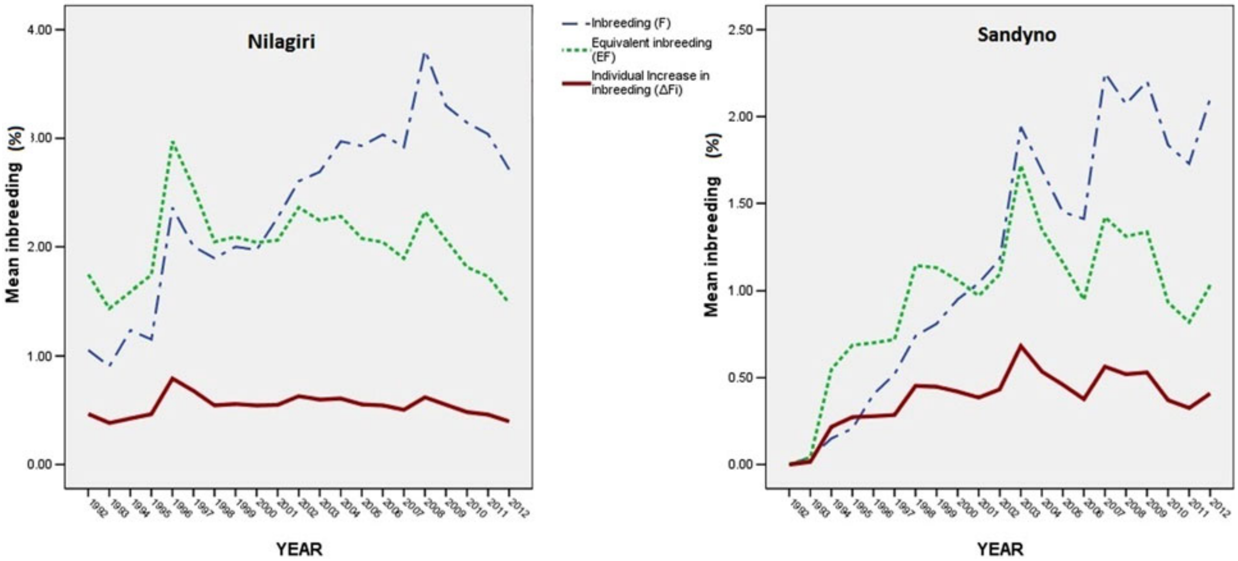

Figure 2. Inbreeding and equivalent inbreeding in Nilagiri and Sandyno sheep, according to the year of birth.

Sandyno (increase from 0 to 95 percent in the 15th generation) sheep, the average inbreeding levels were low for these populations. Negussie, Abegaz and Rege (2002) observed an overall inbreeding of 0.78 percent in a population of tropical fat-tailed Horro sheep, in which the proportion of inbred animals increased to 81 percent.

The fixed factors of CG, sex and litter size had significant ($P < 0.05$) influence on all the body weight traits, while age of dam at lambing influenced the weights at earlier ages up to 9 months. With respect to the growth efficiency traits, CG and sex influenced pre- and post-weaning ADG, while type of birth and age of dam at lambing influenced only the pre-weaning ADG.

The partial regression coefficients of different growth traits on individual inbreeding (F and EF) in Nilagiri and Sandyno sheep are presented in Table 4a. Except for a few negligible values of BW, all other regression coefficients were negative and indicative of depression due to inbreeding. An overview of most studies before 1984 on inbreeding in sheep indicate that, on average, there was a decrease in early growth traits with inbreeding (Lamberson and Thomas, 1984). In Nilagiri sheep, significant effects of F were observed for WW ($P < 0.01$), YW ($P < 0.05$) and pre-weaning ADG ($P < 0.01$). In addition to these traits, 6W, 9W and 18W were also found to be influenced ($P < 0.05$) by EF. In Sandyno sheep, the later growth traits (YW and post-weaning ADG) were influenced ($P < 0.05$) by F and EF. More number of traits were affected by inbreeding in the Nilagiri sheep and this could be due to higher inbreeding levels in the population. Among the significant effects of inbreeding, the depression in growth per 1 percent increase in inbreeding ranged from 0.04 kg in weaning weight to 0.100 kg in yearling weight. Between-breed and within-breed variation in the effect of inbreeding on a particular trait have been observed (Ercanbrack and Knight, 1981; Boujenane and Chami, 1997; Analla, Montilla and Serradilla, 1998; Pedrosa *et al.*, 2010; Zadeh, 2012; Leroy, 2014).

In the present study, BW was not affected by F or EF in both the breeds. BW was one of the traits reviewed for effect of inbreeding by Lamberson and Thomas (1984). Studies on Ossimi, Hampshire and No-tail breeds showed absence of significant effects; while the Merino population showed significant depression with 0.015 kg decrease per 1 percent increase in F. Boujenane and Chami (1997) reported contrasting results for two Moroccan sheep breeds, Sardi and Beni Guil. In Sardi sheep, the individual inbreeding did not have a significant influence on BW, while an increase of 1 percent F decreased BW by 0.0061 kg in Beni Guil breed of sheep. Significant effects of inbreeding of the lamb on birth weight (-0.010 ± 0.003 kg per percent F) in another Indian breed of sheep, Muzaffarnagari, was reported by Mandal *et al.* (2002).

The decrease of 0.048 kg WW per 1 percent increase in F observed in this study was similar to that found by Boujenane and Chami (1997) in Beni Guil and Mandal *et al.* (2002) in Muzaffarnagri sheep. The review by Lamberson and Thomas (1984) reports the average decrease in weaning weight as 0.111 kg per 1 percent inbreeding, with a range from 0.036 to 0.177 kg per percent F. Higher values of depression in WW than those found in the present study were reported in literature (Ercanbrack and Knight, 1991; Dorostkar *et al.*, 2012).

Kumar *et al.* (2008) noticed that inbreeding did not affect birth weight, weaning weight or 6 months body weight in the Chokla breed of sheep significantly. In Iranian Moghani sheep, the body weight traits at birth, 3, 6, 9 and 12 months of age were negative but non-significant for values of inbreeding depression (Dorostkar *et al.*, 2012). Zadeh (2012) observed significant effects of inbreeding on birth, 3, 6 and 12 months body weight for the same Moghani sheep. But negative effects were

Table 4. Partial regression of growth traits on inbreeding (F) and equivalent inbreeding (EF) in Nilagiri and Sandyno populations.

Growth trait	Nilagiri		Sandyno	
	F	EF	F	EF
(a) Individual inbreeding				
BW (kg)	−0.005 ± 0.003	0.004 ± 0.002	0.001 ± 0.004	0.002 ± 0.004
WW (kg)	**−0.048 ± 0.015****	**−0.041 ± 0.012 ****	−0.011 ± 0.017	−0.019 ± 0.018
6W (kg)	−0.038 ± 0.020	−0.031 ± 0.015*	−0.034 ± 0.025	−0.035 ± 0.025
9W (kg)	−0.049 ± 0.027	−0.046 ± 0.019*	−0.055 ± 0.033	−0.063 ± 0.032
YW (kg)	**−0.062 ± 0.031***	**−0.047 ± 0.022***	**−0.100 ± 0.039***	**−0.098 ± 0.038***
18W (kg)	−0.074 ± 0.044	−0.076 ± 0.031*	−0.033 ± 0.062	−0.048 ± 0.065
Pre-ADG (g)	**−0.470 ± 0.153****	**−0.398 ± 0.126****	−0.146 ± 0.174	−0.248 ± 0.188
Post-ADG (g)	−0.052 ± 0.091	−0.029 ± 0.063	**−0.263 ± 0.116***	**−0.273 ± 0.113***
(b) Ewe inbreeding				
BW (kg)	**−0.008 ± 0.004***	**0.007 ± 0.003***	**0.008 ± 0.004***	**0.009 ± 0.004***
WW (kg)	**−0.039 ± 0.018***	**−0.034 ± 0.014***	0.024 ± 0.018	0.029 ± 0.018
6W (kg)	−0.028 ± 0.026	−0.026 ± 0.019	0.010 ± 0.027	−0.009 ± 0.026
9W (kg)	−0.061 ± 0.035	−0.027 ± 0.025	0.023 ± 0.034	0.008 ± 0.031
YW (kg)	**−0.115 ± 0.043****	**−0.095 ± 0.037****	−0.009 ± 0.040	−0.024 ± 0.037
18W (kg)	−0.026 ± 0.060	−0.026 ± 0.053	−0.096 ± 0.054	−0.083 ± 0.048
Pre-ADG (g)	**−0.373 ± 0.185***	**−0.322 ± 0.141****	0.200 ± 0.186	0.244 ± 0.184
Post-ADG (g)	**−0.275 ± 0.125***	−0.200 ± 0.107	−0.216 ± 0.119	−0.202 ± 0.111

BW, birth weight; WW, weaning weight; 6W, 6 months weight; 9W, 9 months weight; YW, yearling weight; 18W, 18 months weight; pre, preweaning; post, postweaning; ADG, average daily gain.
$*P < 0.05$; $**P < 0.01$.

noticed only in the case of birth and 12 months weight. Hussain *et al.* (2006) found significant negative effects of inbreeding on early weight traits (birth and 60 days weight), but the effect diminished as age advanced and a non-significant depression was noticed in the weight at 90 days. Mandal *et al.* (2002) found significant influence of F on pre-weaning ADG. Non-significant influence of F on pre- and post-weaning daily gains in Hissardale sheep from Pakistan were reported by Akhtar *et al.* (2000). The various studies reviewed above are for the effect of inbreeding coefficient F.

Very few studies were available for the effect of ΔF_i on growth in sheep. Pedrosa *et al.* (2010) observed significant influence of ΔF_i on BW and 6W. The reduction per percent increase in ΔF_i was found to be 0.0034 and 0.204 kg, respectively. Gowane *et al.* (2013) reported non-significant effect of ΔF_i on growth in Bharat Merino sheep. The inclusion of individual increase in inbreeding was found to be adequate for quantification of inbreeding depression in growth of Brazilian Marchigiana and Bonsmara breeds of cattle (Santana *et al.*, 2012). Panetto *et al.* (2010) also observed significant effects of inbreeding on age at first calving, average daily milk yield and calving interval by using F and EF as measures of inbreeding in Gyr cattle.

The effect of ewe inbreeding on lamb growth traits is presented in Table 4b. In Nilagiri sheep, F and EF had significant influence on BW, WW, YW and pre-weaning ADG. In addition to these traits, F had influence on post-weaning ADG also. All the significant effects were found to be negative with maximum depression of about 0.1 kg in YW per 1 percent increase in inbreeding. The review by Lamberson and Thomas (1984) also indicate depressive effect of ewe inbreeding on growth traits and greater influence was noticed in BW. Boujenane and Chami (1997) also found negative effect of inbreeding of dam on early growth traits up to 30 days of age. In contrast, both F and EF caused a negligible increase of 0.008 and 0.009 kg, respectively, per 1 percent increase in inbreeding. In this population, none of the other traits were affected by ewe inbreeding. As explained earlier, Sandyno was a more heterogenous population with lower average inbreeding coefficient.

With respect to the effect of level of inbreeding, in Nilagiri sheep (Table 5), both inbreeding (F) and equivalent inbreeding (EF) classes had significant ($P < 0.05$) influence on WW. In addition, F was found to influence ($P < 0.05$) pre-weaning ADG. The class with zero inbreeding was significantly different and superior to other classes for WW and pre-weaning ADG. The least-squares mean for inbreeding level above 12.5 percent was found to be the lowest in all the traits. As seen in earlier studies (Lamberson and Thomas, 1984), earlier growth traits were affected by F and EF in Nilagiri sheep.

In Sandyno sheep (Table 6), none of the traits were affected by F, while EF caused significant ($P < 0.05$) depression in 6W and 9W. Lowest means in these traits were noticed in the fifth level with inbreeding above 12.5 percent. In general, the traits declined with increase in inbreeding and in most of the cases the fifth levels of inbreeding class with more than 12.5 percent of inbreeding showed lower mean values. In earlier studies, the levels of individual inbreeding coefficient, above which depression on growth traits were found to be maximum were reported as 10 percent (Norberg and Sorensen, 2007), 15 percent (Ercanbrack and Knight, 1991), 25 percent (Wiener, Lee and Woolliams, 1992) and 30 percent (Boujenane and Chami, 1997).

Table 5. Estimated mean growth traits for different classes of inbreeding and equivalent inbreeding in Nilagiri sheep.

Trait	Level of inbreeding				
	0%	Up to 3.125%	Up to 6.25%	Up to 12.50%	>12.50%
Inbreeding (F)					
BW	2.36 ± 0.04 (826)	2.30 ± 0.04 (1 578)	2.29 ± 0.4 (527)	2.28 ± 0.05 (167)	2.26 ± 0.07 (56)
WW	**9.97^{a} ± 0.19 (715)**	**9.74^{b} ± 0.17 (1 443)**	**9.59^{b} ± 0.19 (476)**	**9.39^{b} ± 0.24 (148)**	**9.28^{b} ± 0.35 (49)**
6W	13.54 ± 0.25 (628)	13.56 ± 0.24 (959)	13.43 ± 0.26 (306)	13.24 ± 0.34 (99)	12.82 ± 0.50 (31)
9W	16.23 ± 0.36 (557)	16.32 ± 0.35 (779)	15.99 ± 0.37 (247)	15.67 ± 0.47 (81)	15.89 ± 0.73 (21)
YW	19.35 ± 0.42 (517)	19.46 ± 0.42 (690)	19.05 ± 0.45 (224)	18.92 ± 0.55 (72)	18.27 ± 0.85 (19)
18W	24.54 ± 0.55 (396)	25.02 ± 0.54 (572)	24.29 ± 0.59 (185)	23.83 ± 0.72 (58)	24.78 ± 1.18 (14)
Pre-ADG	**84.41^{a} ± 1.99 (715)**	**82.38^{b} ± 1.81 (1 443)**	**80.72^{b} ± 1.94 (476)**	**78.80^{b} ± 2.52 (148)**	**78.23^{b} ± 3.67 (49)**
Post-ADG	33.14 ± 1.27 (517)	34.09 ± 1.25 (690)	33.71 ± 1.35 (224)	33.56 ± 1.65 (72)	30.49 ± 2.55 (19)
Equivalent inbreeding (EF)					
BW	2.36 ± 0.04 (826)	2.30 ± 0.03 (1 772)	2.29 ± 0.04 (360)	2.30 ± 0.05 (137)	2.26 ± 0.07 (59)
WW	**9.94^{a} ± 0.19 (715)**	**9.68^{b} ± 0.17 (1 620)**	**9.73^{b} ± 0.19 (325)**	**9.36^{b} ± 0.26 (121)**	**9.31^{b} ± 0.35 (50)**
6W	13.53 ± 0.25 (628)	13.48 ± 0.23 (1 034)	13.58 ± 0.28 (230)	13.58 ± 0.35 (88)	12.77 ± 0.44 (43)
9W	16.21 ± 0.36 (557)	16.16 ± 0.35 (831)	16.35 ± 0.39 (187)	16.12 ± 0.47 (77)	15.21 ± 0.62 (33)
YW	19.31 ± 0.43 (517)	19.35 ± 0.42 (738)	19.27 ± 0.47 (168)	19.24 ± 0.56 (67)	18.30 ± 0.71 (38)
18W	24.47 ± 0.55 (396)	25.01 ± 0.54 (624)	23.65 ± 0.62 (127)	25.13 ± 0.74 (54)	23.50 ± 0.97 (24)
Pre-ADG	84.12 ± 1.99 (715)	81.73 ± 1.81 (1 620)	82.25 ± 2.05 (325)	77.95 ± 2.67 (121)	78.97 ± 3.67 (50)
Post-ADG	33.07 ± 1.27 (517)	33.99 ± 1.25 (738)	33.36 ± 1.40 (168)	34.73 ± 1.68 (67)	32.25 ± 2.11 (38)

Traits with significant effects are in bold. Subclass means bearing different superscripts are different ($P < 0.05$) from each other.

Among the traits for which inbreeding classes had significant influence, weightage given to individuals based on the differences in EqG$_i$ resulted in changes in the distribution of data between inbreeding classes of F and EF. Compared with frequency distribution of F classes, EF classes showed an increase in the number for the extreme classes 2 and 5 (<3.125 percent and >12.5 percent) and decrease in number for the intermediate classes 3 and 4 (from 3.125 up to 12.5 percent), in both the populations. This difference was more evident in the Sandyno breed, with lesser pedigree information.

In the present study, the two populations, Nilagiri and Sandyno showed variations in the magnitude and type of traits affected by inbreeding. More traits, especially those at early age were affected by inbreeding in the Nilagiri population, in which inbreeding was high (Table 4). The average inbreeding (both F and EF) in the Sandyno was lesser than that of Nilagiri population. Probably, in the Sandyno population inbreeding has not reached sufficient levels to cause depression in the unaffected traits. Moreover, the Nilagiri breed is more uniform and has been under selection for a longer period of time, while Sandyno is a newer breed, more heterogenous than Nilagiri sheep (Table 2).

Inbreeding depression was noticed in some of the growth traits in Nilagiri and Sandyno breeds of sheep.

Table 6. Estimated mean growth traits for different classes of inbreeding and equivalent inbreeding in Sandyno sheep.

Trait	Level of inbreeding				
	0%	Up to 3.125%	Up to 6.250%	Up to 12%	>12%
Inbreeding (F)					
BW	2.49 ± 0.07 (1 834)	2.53 ± 0.07 (2 023)	2.49 ± 0.08 (242)	2.59 ± 0.87 (105)	2.48 ± 0.11 (41)
WW	10.10 ± 0.40 (1 421)	10.20 ± 0.40 (1 888)	10.26 ± 0.42 (227)	9.94 ± 0.46 (98)	10.04 ± 0.54 (39)
6W	15.49 ± 0.57 (1 159)	15.54 ± 0.56 (1 026)	15.68 ± 0.61 (135)	15.18 ± 0.66 (63)	14.57 ± 0.85 (19)
9W	18.99 ± 0.79 (1 006)	18.84 ± 0.77 (819)	18.63 ± 0.83 (105)	18.48 ± 0.89 (53)	17.42 ± 1.17 (13)
YW	23.37 ± 0.91 (925)	23.31 ± 0.89 (729)	22.97 ± 0.97 (93)	22.53 ± 1.03 (52)	21.61 ± 1.38 (12)
18W	28.25 ± 1.17 (851)	28.37 ± 1.14 (602)	28.52 ± 1.26 (78)	27.72 ± 1.36 (41)	27.19 ± 2.12 (7)
Pre-ADG	84.62 ± 4.17 (1 421)	85.24 ± 4.09 (1 888)	86.54 ± 4.32 (227)	81.61 ± 4.75 (98)	84.28 ± 5.60 (39)
Post-ADG	42.94 ± 2.72 (925)	42.74 ± 2.66 (729)	40.65 ± 2.88 (93)	41.25 ± 3.07 (52)	38.87 ± 4.13 (12)
Equivalent inbreeding (EF)					
BW	2.48 ± 0.07 (1 834)	2.53 ± 0.07 (2 143)	2.54 ± 0.08 (165)	2.40 ± 0.09 (70)	2.60 ± 0.11 (33)
WW	10.08 ± 0.40 (1 421)	10.23 ± 0.40 (2 008)	10.16 ± 0.43 (148)	10.05 ± 0.49 (66)	9.39 ± 0.60 (30)
6W	**15.46^{a} ± 0.57 (1 159)**	**15.53^{a} ± 0.56 (1 082)**	**15.81^{a} ± 0.63 (97)**	**15.94^{a} ± 0.72 (38)**	**13.74^{b} ± 0.79 (26)**
9W	**18.95^{ab} ± 0.79 (1 006)**	**18.83^{a} ± 0.77 (858)**	**19.18^{ab} ± 0.85 (81)**	**18.51^{b} ± 0.95 (33)**	**16.50^{c} ± 1.08 (18)**
YW	23.26 ± 0.92 (925)	23.32 ± 0.89 (766)	23.00 ± 0.99 (73)	22.26 ± 1.11 (31)	21.25 ± 1.28 (16)
18W	28.13 ± 1.17 (851)	28.43 ± 1.14 (632)	27.65 ± 1.28 (67)	27.77 ± 1.55 (21)	27.59 ± 2.03 (8)
Pre-ADG	84.44 ± 4.17 (1 421)	85.64 ± 4.09 (2 008)	84.39 ± 4.47 (148)	85.04 ± 5.02 (66)	75.85 ± 6.01 (30)
Post-ADG	42.69 ± 2.73 (925)	42.72 ± 2.66 (766)	41.29 ± 2.96 (73)	39.97 ± 3.32 (31)	38.12 ± 3.85 (16)

Traits with significant effects are in bold. Means bearing different superscripts within a row are different ($P < 0.05$) from each other.

Magnitude of depression was more with levels of inbreeding greater than 12.5 percent inbreeding. Inbreeding depression was found in more number of traits in the Nilagiri population, which was more inbred and less heterogenous than the Sandyno population. Even though inbreeding is usually known to affect fitness traits, depressive effects are also evident in production traits like growth. EF was higher than F for individual animals with lesser pedigree depth during earlier generations in both the populations. The trend of F and EF over years indicates that EF adjusts for the differences in pedigree knowledge and prevents overestimation of inbreeding during later generations, when individuals have greater depth in their pedigrees. In Sandyno sheep with lesser pedigree information, EF as covariate showed greater magnitude of depression and EF included as fixed classes showed more traits to be significant compared with F. EF can be used as an alternative measure of inbreeding, especially when deficiency in ancestral knowledge could lead to potential bias in the values of traditional F.

Acknowledgements

The authors thank the Director of the Centre for Animal Production Studies, TANUVAS for permitting to utilize the data from SBRS, Sandynallah for this study, which is part of Ph.D. programme of the first author at Madras Veterinary College, TANUVAS, Chennai. The contributions of the staff of animal breeding at the research station in recording and maintenance of data is acknowledged.

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Animal Genetic Resources, 2016, 58, 73–82. © Food and Agriculture Organization of the United Nations, 2016
doi:10.1017/S2078633616000023

The impact of racial pattern on the genetic improvement of Morada Nova sheep

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Summary
The objective of the present study was to describe the frequency of the main racial traits of Morada Nova sheep and simulate the impact of this culling on the response to selection for birth weight. The data from sex, coat colour, hoof pigmentation, muzzle pigmentation, polled and cryptorchidism were collected individually at weaning from 385 Morada Nova sheep of the red variety, born between 2010 and 2012, which belonged to four different flocks in the state of Ceará, Brazil. To estimate the impact of culling of animals due to racial pattern on the genetic improvement of the Morada Nova population, the genetic gains in birth weight per generation were calculated considering the following different scenarios of culling due to racial pattern in a simulated population. The present results indicate that the most urgent step is flexibilization of the requirement of dark muzzles and hooves. The selection of Morada Nova sheep based on racial pattern has caused losses in the genetic gain for productive traits such as birth weight. Readaptation of the official racial pattern established for Morada Nova sheep is necessary so that the racial pattern is achieved and an adequate number of animals will be available for selection.

Keywords: *Body weight, in situ conservation, local breed*

Résumé
Le but de cette étude a été de déterminer la fréquence des principaux traits raciaux des moutons de race Morada Nova et d'estimer l'impact du rejet pour la non-adéquation au standard de la race sur la réponse à la sélection par poids à la naissance. Les informations sur le sexe, la couleur de la robe, la pigmentation des onglons, la pigmentation du mufle, le manque de cornes et la cryptorchidie ont été recueillies individuellement au sevrage sur 385 agneaux Morada Nova de la variété rousse, nés entre 2010 et 2012. Ces agneaux appartenaient à quatre troupeaux différents de l'état du Ceará au Brésil. Afin d'estimer l'effet du rejet d'animaux pour la non-adéquation au standard racial sur l'amélioration génétique de la population Morada Nova, les gains génétiques de poids à la naissance par génération ont été calculés en considérant les suivantes situations de rejet en raison du standard racial dans une population simulée. Les résultats montrent que la première mesure à prendre est l'assouplissement de la condition de mufle et onglons foncés. La sélection des ovins de race Morada Nova selon le standard racial est à l'origine de pertes de gain génétique pour des caractères productifs tels que le poids à la naissance. La réadaptation du standard racial officiel des ovins Morada Nova s'avère nécessaire de telle sorte que le standard de la race puisse être satisfait en laissant toutefois un nombre suffisant d'animaux disponibles pour la sélection.

Mots-clés: *poids corporel, conservation in situ, race locale*

Resumen
El objetivo del presente estudio fue determinar la frecuencia de los principales rasgos raciales de las ovejas Morada Nova y simular el impacto del descarte por incumplimiento del patrón racial sobre la respuesta a la selección por peso al nacimiento. Los datos de sexo, colour de la capa, pigmentación de las pezuñas, pigmentación del hocico, falta de cuernos y criptorquidia fueron tomados individualmente al destete sobre 385 corderos Morada Nova de la variedad roja, nacidos entre 2010 y 2012. Estos corderos pertenecieron a cuatro rebaños distintos del estado de Ceará, en Brasil. Para estimar el efecto del descarte de animales por incumplimiento del patrón racial sobre la mejora genética de la población Morada Nova, los incrementos genéticos del peso al nacimiento por generación fueron calculados considerando las siguientes situaciones de descarte por patrón racial en una población simulada. Los resultados indican que la medida más urgente es la flexibilización del requisito de hocico y pezuñas oscuros. La selección del ganado ovino Morada Nova por patrón racial ha causado pérdidas de ganancia genética en caracteres productivos tales como el peso al nacimiento. Se hace necesario readaptar el patrón racial oficial establecido para el ganado ovino Morada Nova de tal manera que se pueda alcanzar el patrón racial manteniendo aun así un número adecuado de animales disponibles para la selección.

Palabras clave: *peso corporal, conservación in situ, raza local*

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[†] The preparation of this paper has been overshadowed by Silva's death. We had intend to write jointly: most of the main ideas were worked out together and I have done my best to complete them. In sorrow, I dedicate this work to his memory.

Submitted 29 July 2015; accepted 5 November 2015

Introduction

Morada Nova sheep are small animals adapted to the semi-arid climate of northeastern Brazil, which exhibit high prolificacy and no reproductive seasonality (Facó *et al.*, 2008). In extensive farming systems such as those that predominate in the northeastern region of Brazil, the small size of the animals is a strategical advantage, particularly during periods of feed scarcity when the nutritional requirements for maintenance of small animals are lower than those of large animals (Silva, La Scala Jr. and Tonhati, 2003; Gonzaga Neto *et al.*, 2005; NRC, 2007). On the other hand, the birth of very low weight animals increases lamb mortality during the preweaning period (Everett-Hincks *et al.*, 2014), a fact that becomes even more important in extensive farming systems.

In 2007, a centre for genetic improvement was formed with the participation of Morada Nova sheep breeders from the region of origin of the breed (Facó *et al.*, 2009). The first years of this work revealed the existence of a high rate of lamb mortality during the preweaning period. In view of the genetic variability in birth weight demonstrated by Shiotsuki *et al.* (2014), selection for higher birth weight in this population would have indirect benefits, such as a reduction in mortality (Everett-Hincks *et al.*, 2014), with positive impacts on the genetic improvement of the population studied.

However, animals of this population are frequently removed from breeding because they do not comply with the official racial pattern. This pattern, which was approved by the Ministry of Agriculture, Livestock and Food Supply (Ministério da Agricultura, Pecuária e Abastecimento – MAPA) and is maintained by the Brazilian Association of Sheep Breeders (Associação Brasileira de Criadores de Ovinos – ARCO), establishes a coat colour ranging from light to dark red, dark coloured hooves and muzzle, no horns or only rudiments, and the absence of cryptorchidism for the red variety of the Morada Nova breed (ARCO, 2015). A high culling rate of animals due to the lack of compliance with the established racial pattern may reduce the number of animals suitable for selection and the intensity of selection, and consequently affect the genetic gain that could be obtained with selection.

Therefore, the objective of the present study was to describe the frequency of the main racial traits of Morada Nova sheep and simulate the impact of this culling on the response to selection for birth weight.

Material and methods

Data collected at weaning from 385 Morada Nova sheep of the red variety, born between 2010 and 2012, which belonged to four different flocks in the state of Ceará, Brazil, were used. The data were collected individually before any selection and the following variables were studied: sex, coat colour, hoof pigmentation, muzzle pigmentation, polled and cryptorchidism.

Coat colour was classified as red (Figure 1A) or black (Figure 1B). It should be noted that animals with a black coat are usually culled because they do not comply with the official racial pattern (ARCO, 2015).

Another feature considered for standardization is pigmentation of the muzzle, which was classified as follows:

- pigmented: completely pigmented mucosa (Figure 2A);
- predominantly pigmented (animals with more than 50 percent muzzle pigmentation) (Figure 2B);
- predominantly depigmented (animals with less than 50 percent muzzle pigmentation) (Figure 2C);
- depigmented (animals without muzzle pigmentation) (Figure 2D).

Hoof pigmentation is also a feature of the racial pattern. Hooves were evaluated together in each animal. Thus, a single degree of overall pigmentation was assigned to each animal considering the four hooves and classified as follows:

- pigmented: animals with completely pigmented hooves (Figure 3A);
- predominantly pigmented (animals with more than 50 percent hoof pigmentation (Figure 3B);
- predominantly depigmented (animals with less than 50 percent hoof pigmentation (Figure 3C);
- depigmented (animals without hoof pigmentation) (Figure 3D).

Animals with muzzle and/or hoof pigmentation classified as predominantly depigmented and depigmented are considered defective or outside the racial pattern and are therefore culled from the flock.
Animals with horns are also culled. The presence or absence of horns was defined as:

- animals with horns if horns (Figure 4A) were present;
- polled animals if horns were rudiments (Figure 4B) or absent (Figure 4C).

Animals in which the testes fail to descend are considered outside the racial pattern. In addition, these animals are infertile or subfertile. Testicular descent was classified as follows:

- normal: no failure of testicular descent or absence of cryptorchidism (Figure 5C);
- cryptorchidic: failure of one (unilateral cryptorchidism, Figure 5B) or both testes (bilateral cryptorchidism, Figure 5A) to descend.

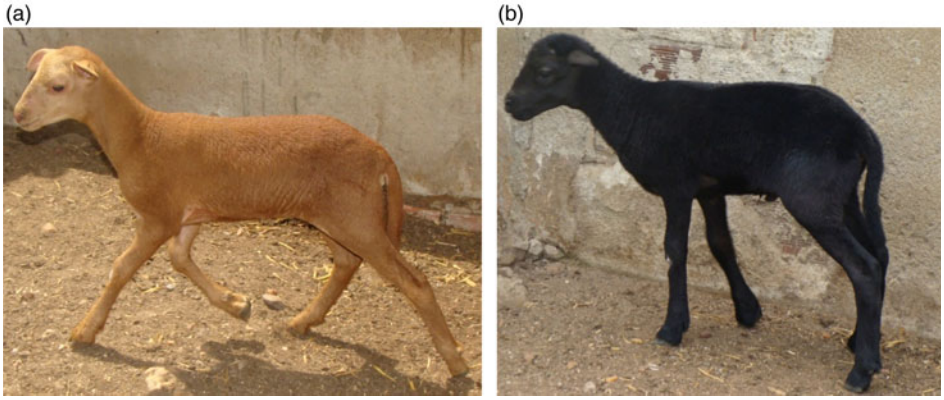

Figure 1. Morada Nova sheep with red (a) and black (b) coat colour.

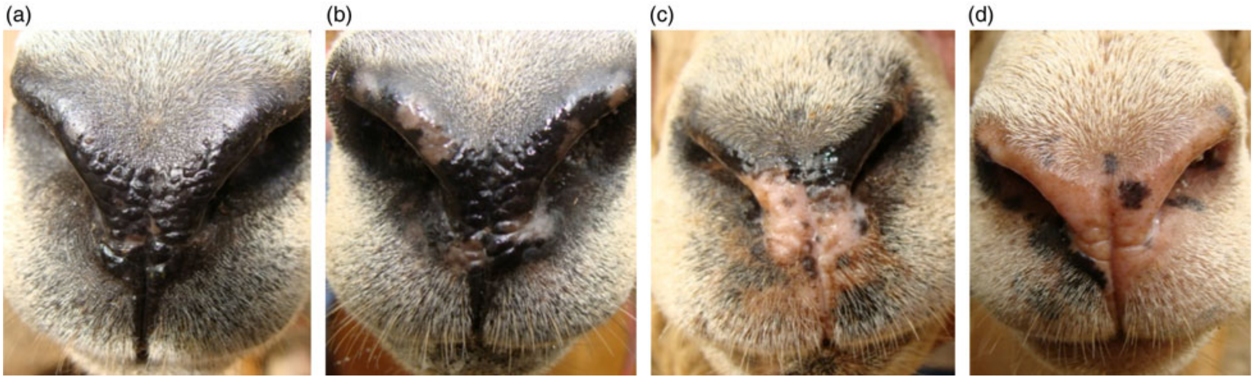

Figure 2. The muzzle pigmentation degree in Morada Nova sheep: Pigment (a), predominantly pigmented (b), predominanthly dudley (c) and Dudley (d).

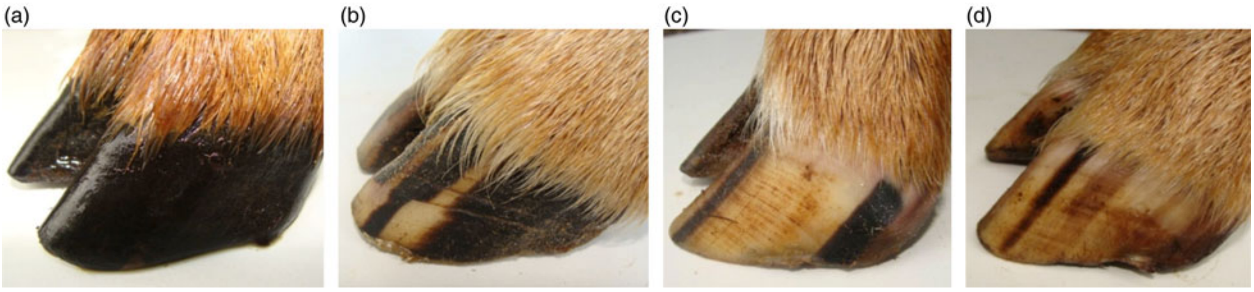

Figure 3. Degree of pigmentation in hooves of Morada Nova sheep: Pigmented (a), predominantly pigmented (b), predominantly Dudley (c) and Dudley (d).

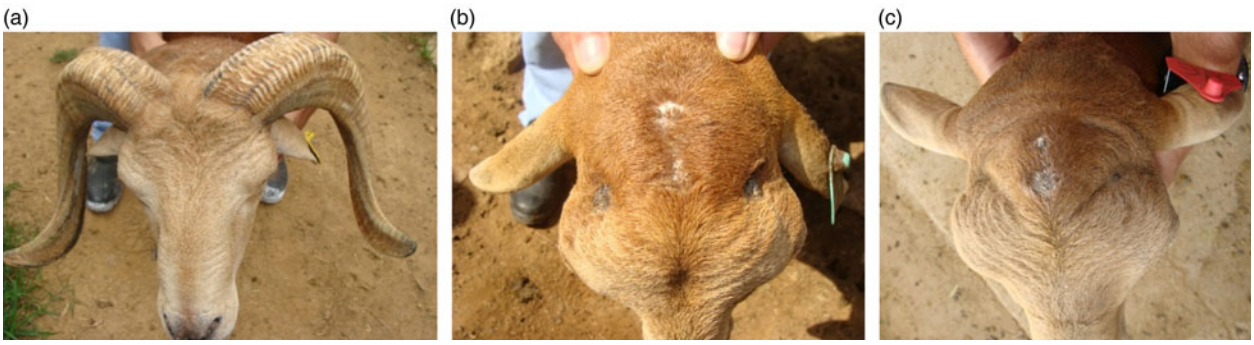

Figure 4. Presence of horn (a), presence of rudiment (b) and absence of horns (c) in Morada Nova sheep.

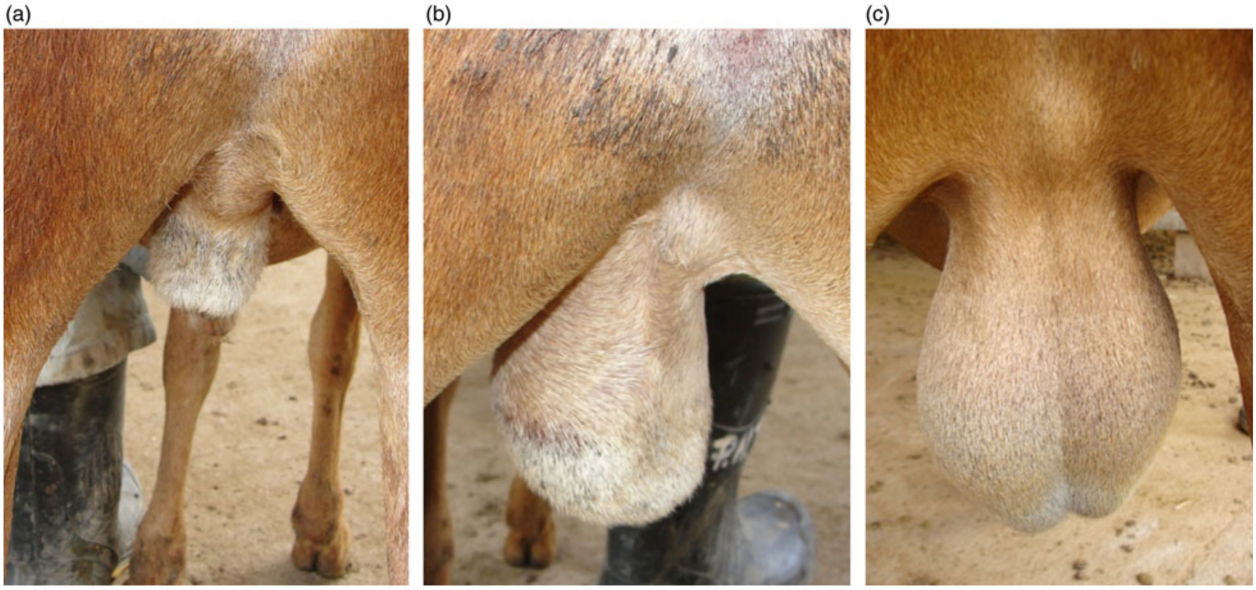

Figure 5. Bilateral cryptorchidism (a), unilateral cryptorchidism (b) and normal testes (c) in Morada Nova sheep.

The data were analysed statistically by the chi-squared test (χ^2). For this purpose, the variables are listed in contingency tables. The χ^2 test was used to evaluate the following associations:

– Between muzzle pigmentation and hoof pigmentation: to evaluate the association between these traits, it was necessary to divide them into two levels: class 1 was attributed to animals with less than 50 percent pigmentation of the muzzle or hooves (predominantly depigmented and depigmented), while class 2 was attributed to animals with more than 50 percent pigmentation of the muzzle or hooves (predominantly pigmented and pigmented). This classification of hoof and muzzle pigmentation was used to permit a more direct interpretation of the results.
– Between sex and hornlessness: for the hornless trait, animals with rudiments and animals with horns were grouped in a single class due to the difficulty in differentiating these animals.
– Between cryptorchidism and hornlessness: for application of the chi-squared (χ^2) test, animals with bilateral and unilateral cryptorchidism were grouped in a single class.

According to McDonald (2014) when the sample sizes are too small (an expected number is less than 5), an alternative, such as an exact test of goodness-of-fit or a Fisher's Exact Test of Independence. The Fisher's Exact Test was used to evaluate the following associations since expected number was less than 5:

– Between coat colour and flocks;
– Between flocks and hornlessness.

The frequencies of animals culled due to racial pattern were used to verify the impact of this culling on the genetic gain in birth weight per generation. First, a χ^2 test was applied between sex and all traits analyzed to determine whether the dispersion of frequency depends on sex. For traits that were not dependent on sex, the same culling rate was considered for males and females. Additionally, a zero culling rate for sex was assumed when the trait was not expressed, as was the case of horns and cryptorchidism in females. Birth weight was chosen as a trait since it is easily measured and subject to few errors and loss of information.
To estimate the impact of culling of animals due to racial pattern on the genetic improvement of the Morada Nova population, the genetic gains in birth weight per generation were calculated considering the following different scenarios of culling due to racial pattern in a simulated population:

scenario 1: absence of culling of animals due to racial characteristics;
scenario 2: animals culled because of a black coat;
scenario 3: animals culled because of hoof and/or muzzle depigmentation;
scenario 4: animals culled because of the presence of horns;
scenario 5: animals culled because of a black coat, hoof depigmentation, muzzle depigmentation, and presence of horns.

The formula described by Falconer and Mackay (1996) was used for these estimations:

$$\Delta G = \left\{ \left[\frac{(im + if)}{2} \right] * h^2 * \sigma p \right\};$$

where ΔG = genetic gain i_m = selection intensity for males; i_f = selection intensity for females; h^2 = heritability of the trait; σ_p = phenotypic standard deviation of the trait;
The heritability ($h^2 = 0.19 \pm 0.08$) of birth weight used to calculate the genetic gains per generation was obtained

from Shiotsuki *et al.* (2014). The selection intensities for males and females were calculated as a function of the proportion of animals selected to meet replacement rates of 20 and 50 percent for males and females, respectively. The number of males and females available for selection was obtained considering a flock of 500 ewes, with one ram per 25 ewes, and the fertility, prolificacy and mortality rates described by Lôbo *et al.* (2011) and the culling rates due to cryptorchidism summarized in Table 1.

The proportion of animals selected in both sexes was calculated by the ratio between the number of females or males necessary to meet the replacement rates and the number of females or males available for selection after culling due to racial pattern. The intensities of selection for males and females according to each proportion selected before and after culling due to racial pattern were obtained using an Excel spreadsheet elaborated by Van Der Werf (2011). The losses of genetic gain in birth weight were calculated considering the ratio between genetic gain after culling due to racial pattern and genetic gain before culling due to racial pattern, −100 percent by the result of this ratio.

Table 1. Herd structure and parameters assumed to calculate the genetic gain for birth weight in Morada Nova breed

Parameters	Values
Number of ewe	500
Number of sires	20
Fertility (%)	85
Prolificacy	1.45
Mortality (%)	15
Replacement rate of ewes (%)	20
Replacement rate of sires (%)	50
Number of females to be selected for replacement	100
Number of males to be selected for replacement	10
Number of females apt to selection	261.91
Disposal rate by the presence of cryptorchidism in males (%)	16.42
Number of males apt for selection	218.90

Results

No association was observed between coat colour and flock by the χ^2 test (Table 2) and almost 3 percent of the animals are culled due to coat colour outside the racial pattern. With respect to the muzzle, the proportion of individuals with a depigmented or predominantly depigmented muzzle (class 1) was similar to the proportion of animals with a pigmented or predominantly pigmented muzzle (class 2) (Table 3).

When hoof pigmentation of Morada Nova sheep is considered, 23.9 percent of the animals evaluated would be culled exclusively due to this characteristic, i.e. the animal would be culled irrespective of its productive and reproductive skills following the official racial pattern (Table 3).

Approximately 58 percent of the animals of the population studied would be culled due to the predominance of a depigmented muzzle and/or hooves (Table 4), since these animals would not obtain the definitive genealogical record. Only 42.34 percent of the animals studied would comply with the racial pattern for these two characteristics.

According to the official racial pattern, 9.95 percent of males would be culled due to the presence of horns, regardless of their genetic potential for other traits. On the other hand, none of the females exhibited this characteristic and a significant association was observed between sex and polled (Table 5). This association suggests that the horn can be related to sex heritage, however, further studies are needed to confirm.

In males, 16.42 percent were cryptorchid despite intense selection against this trait (Table 6). The culling of animals because of the lack of compliance with the official racial pattern reduced the number of males and females available for selection (Table 7). There was a significant association between cryptorchidism and polled (Table 8).

A strong negative impact of culling animals with less than 50 percent hoof and muzzle pigmentation on genetic gain (loss of 37.1 percent in genetic gain) was observed in the present study. When the animals were culled due to all characteristics imposed by the racial pattern (coat colour, hoof pigmentation, muzzle pigmentation, and presence of horns), the loss in genetic gain was even greater (46 percent).

Discussion

Coat colour is a selection criterion for Morada Nova sheep according to the official racial pattern (ARCO, 2015). Animals with a black coat colour are not accepted by the racial pattern. However, the results indicate that animals with this coat colour can appear in any Morada Nova flock, even when selection is performed against this trait. There are no studies in the literature investigating the inheritance of coat pigmentation in Morada Nova sheep. However, in individuals of other breeds and other species the dominant allele (A^{Wt}) of the Agouti locus is responsible for a yellow or red coat colour, while animals homozygous for the recessive allele (A^{a}) have a black or brown coat (Searle, 1968; Brooker and Dolling, 1969; Jackson, 1994; Lu *et al.*, 1994; Cone *et al.*, 1996). Considering that the coat colour in Morada Nova sheep is expressed by the action of a single gene with complete dominance, the selection against a black coat (recessive) becomes progressively slower because a larger proportion of the recessive allele is protected in heterozygous individuals. In our study, the frequency of this allele would be 0.1691, and 85 percent of these alleles are in heterozygotes.

Black animals are culled not only based on the criterion of the genealogical records, but also because of the marked rejection by breeders, who understand this selection as a

Table 2. Frequency dispersion of coat colour in the herd Morada Nova breed

Coat colour	Herd								Total	
	1[a]		2[a]		3[a]		4[a]			
	N	(%)	*N*	(%)	*N*	(%)	*N*	(%)	*N*	(%)
Red	60	95.24	261	97.03	20	100.00	33	100.00	374	97.14
Black	3	4.76	8	2.97	0	0.00	0	0.00	11	2.86
Total	63	100.00	269	100.00	20	100.00	33	100.00	385	100.00

N = number of animals according with its coat colour; ($\chi^2 = 2.39$; $P < 0.05$); [a] herds have red or black coat frequency statistically similar by the Fisher's test.

Table 3. Number of animals per degree of pigmentation of the muzzle and the hooves of sheep Morada Nova breed

Degree of pigmentation		Muzzle		Hooves	
		N	(%)	N	(%)
Class 1	Dudley	33	8.57	15	3.90
	Predominantly depigmented	163	42.34	77	20.00
Class 2	Predominantly pigmented	138	35.85	101	26.23
	Pigmented	51	13.25	192	49.84

N = Number of animals; Class 1 = In this class was considered dudley and predominantly depigmented animals; Class 2 = In this class was considered predominantly pigmented and pigmented animals.

means to maintain the adaptability of the breed, since animals with dark skin and a light coat are more adapted to the climatic conditions of subtropical and tropical regions (McManus *et al.*, 2009). Within this context, Silva, La Scala Jr. and Tonhati (2003) showed that light-coloured animals reflect more light and absorb 40–50 percent less radiation than dark-coloured animals. Furthermore, heat stress directly affects reproductive functions (particularly embryo development and gestation), growth, and water and food intake (Silva, 2000). Hence, the use of coat colour as a culling criterion would protect the adaptive ability that the breed possessed originally.

Pigmentation of the muzzle showed an almost normal distribution, in which the central classes (predominantly depigmented and predominantly pigmented) contained the largest number of individuals, while the frequency of pigmented and depigmented animals was lower. Following the racial pattern of Morada Nova sheep, slightly more than half of the animals would be culled due to this characteristic. This culling rate is high, especially when considering that there are no studies comparing the benefits or disadvantages of this pigmentation for sheep production.

There are no studies on the chemical composition of hooves in sheep. However, a study on Mangalarga Marchador horses found no difference in dry matter, crude protein, ether extract, ashes, calcium, phosphorus, copper, zinc, amino acid profile or biotin between light and black hooves (Faria *et al.*, 2005). Also in horses, Butler (1992) and Nascimento (1999) confirmed that the dark pigment in hooves does not improve quality or resistance. Taken together, there is no evidence justifying the depreciation of light-coloured hooves over black hooves since their amino acid composition is very similar. In Morada Nova sheep, hoof pigmentation is more related to visual features rather than any adaptive trait. However, no study has been conducted to confirm this observation. Thus, culling animals taking into consideration only hoof colour may not be a good parameter since studies establishing any type of association between hoof colour and resistance to diseases are sparse.

A significant association was observed between muzzle and hoof pigmentation, i.e. it is more likely that animals with a pigmented muzzle also exhibit pigmented hooves. This type of association is desirable since the official racial pattern establishes that Morada Nova sheep should have a dark muzzle and dark hooves. In practice, breeders do not keep animals that do not comply with the racial pattern, especially as sires since there is no added value of animals of this breed without a genealogical record.

It is known that in animals, especially mammals, pigmentation is mainly determined by the relative amount of melanin, eumelanin (black or brown) or pheomelanin (yellow or red). Furthermore, the production of melanin is controlled by alleles of the Agouti and extension loci (Searle, 1968; Jackson, 1994). Possibly, pigmentation of the hooves, muzzle and coat is controlled by the same alleles of the Agouti locus and may be genetically the same trait. Additionally, all animals with a black coat have a completely pigmented muzzle and hooves, suggesting that the three characteristics (coat colour, muzzle pigmentation, and hoof pigmentation) are determined by the same set of genes. It is necessary to test this hypothesis since, if confirmed, it would make it virtually impossible to achieve the established racial pattern. In this respect, the more pigmented the muzzle and hooves, the greater the likelihood of birth of black animals and, consequently, animals that do not comply with the racial pattern.

Another characteristic defined by the racial pattern is that Morada Nova sheep are polled. One advantage of the presence of horns in sheep, especially in extensive systems, is that these animals can use their horns as a defensive weapon against the aggression of predators. Under conditions of wild sheep creation, the horn plays an important

Table 4. Frequency dispersion between pigmentation of muzzle and hooves classes in Morada Nova breed

Pigmentation	Hooves					
	Class 1		Class 2		Total	
Muzzle	No of records	% TEM	No of records	% TEM	No of records	%
Class 1	66	17.14	130	33.77	196	50.91
Class 2	26	6.75	163	42.34	189	49.09
Total	92	23.90	293	76.10	385	100

%TEM = percentage of total effective number; Class 1 = In this class was considered dudley and predominantly depigmented animals; Class 2 = In this class was considered predominantly pigmented and pigmented animals; ($P = 4.635 \times 10^{-06}$) for Fisher's exact Test).

Table 5. The frequency dispersion of polled in Morada Nova sheep

Sex	Character							
	Polled			Presence of horn			Total	
	N	(%/sex)	(% ET)	*N*	(%/sex)	(% ET)	*N*	(%)
Female	184	100.00	47.79	0	0.00	0.00	184	47.79
Male	181	90.05	47.01	20	9.95	5.19	201	52.21
Total	365		94.81	20		5.19	385	100.00

N = Number of animals; % ET = percentage of the total effective; %/sex = percentage by sex; ($\chi^2 = 13.31$; $P < 0.05$).

Table 6. The frequency dispersion of males polled by herds in Morada Nova sheep

Herd	Character				
	Polled		Presence of horn		Total
	N	(% por rebanho)	*N*	(% por rebanho)	*N*
1[a]	39	92.86	3	7.14	42
2[a]	122	88.41	16	11.59	138
3[a]	7	100.00	0	0.00	7
4[a]	13	92.86	1	3.03	14
Total	181	90.05	20	9.95	201

N = number of animals; ($\chi^2 = 1.68$; $P < 0.05$); Herds followed by different letters have polled and presence of horn frequency statistically different by the Fisher's test ($P < 0.05$).

role in the competition between males for access to ewes (Johnston *et al.*, 2011). On the other hand, polled is valued by breeders mainly because of the ease of management and transport and skin quality. Dolling (1970) observed in Australian Merino sheep that the autosomal Hoh1 allele (Ho locus) produces sex-limited horns.

No significant association was observed between flock and polled and the frequency of animals with horns was similar in all flocks. These results highlight the importance that all breeders give to this type of characteristic and consequently to the culling of these animals, since animals with horns or rudiments do not obtain a genealogical record. The frequency of animals with horns was 30 percent lower than that observed in the Soay sheep population, which are wild animals that mate at random (Johnston *et al.*, 2011). The frequency of Morada Nova sheep with horns would probably be higher if the animals mate at random.

No cryptorchid animal with horns was observed and all animals with problems of cryptorchidism were hornless. It is therefore possible that selection for hornless animals as required by the racial pattern increases the frequency of animals with problems of cryptorchidism. Cryptorchidism animals are culled not only to comply with the racial pattern, but also due to the fact that these animals are infertile or subfertile, causing great damage to the flock.

The genes encoding insulin-like hormone 3 (INSL3) and relaxin/insulin-like family peptide receptor 2 (RXFP2) have been reported by several authors to be responsible for testicular descent (Nef and Parada, 1999; Zimmermann *et al.*, 1999; Emmen *et al.*, 2000; Overbeek *et al.*, 2001; Adham *et al.*, 2002; Kumagai *et al.*, 2002; El Houate *et al.*, 2007; Feng *et al.*, 2007, 2009; Yuan *et al.*, 2010). RXFP2 is associated with the cryptorchid phenotype in dogs (Zhao, Du and Rothschild, 2010), rats (Zimmermann *et al.*, 1999; Yuan *et al.*, 2006; Feng *et al.*, 2009), and humans (Foresta and Ferlin, 2004; El Houate *et al.*, 2007; Feng *et al.*, 2009). Furthermore, a reduction in the action of INSL3 has been suggested to be a possible cause of cryptorchidism in rats (Nef and Parada, 1999). Similarly, INSL3-deficient rats exhibited bilateral cryptorchidism (Zimmermann *et al.*, 1999). It is possible that the occurrence of cryptorchid animals in the Morada Nova breed is due to the action of these genes.

Since there are no studies investigating the association between these genes and cryptorchidism in sheep, it is important to test this hypothesis in future studies. The hypothesis of genetic linkage between INSL3 and RXFP2 does not seem reasonable since the two genes

Table 7. Impact on the genetic gain (ΔG) for birth weight by generation in sheep of Morada Nova breed when there is no disposal of animals by breed standard (Scenario 1), when animals are discarded because the black coat (Scenario 2) animals discarded by depigmentation of the hull and/or nasal mirror (Scenario 3), animals are discarded by the presence of horn (Scenario 4) and when animals are discarded by the black coat, depigmentation of hooves, nasal depigmentation mirror and presence of horn (Scenario 5)

	NFS	NMS	PFD (%)	PMD (%)	PFS (%)	PMS (%)	ISF	ISM	ΔG	PΔG (%)
Scenario 1	261.91	218.90	0.00	0.00	40.46	4.57	0.99	2.17	0.178	0.0
Scenario 2	254.42	212.64	2.86	2.86	40.46	4.84	0.98	2.16	0.176	1.0
Scenario 3	110.89	92.68	57.66	57.66	90.18	25.48	0.19	1.80	0.112	37.1
Scenario 4	261.91	197.12	0.00	9.95	38.18	4.24	0.99	2.14	0.176	1.1
Scenario 5	103.90	74.27	60.33	66.07	96.25	13.43	0.10	1.61	0.096	46.0

NFS, Number of females apt to selection; NMS, Number of males apt for selection; PFD, Discarded Females proportion; PMD, Proportion of discarded males; PFS, Proportion of selected females; PMS, Proportion of selected males; ISF, Intensity females selection; ISM, Intensity males selection; ΔG, Genetic gain; PΔG, Loss of genetic gain for the disposal of racial pattern (%).

Table 8. Frequency dispersion between cryptorchidism and the polled in males of Morada Nova breed

Cryptorchidism	Character				
	Polled		Presence of horn		Total
	N	(% by herd)	*N*	(% by herd)	(%)
Absence	148	73.63	20	9.95	83.58
Presence*	33	16.42	0	0.00	16.42
Total	181	90.05	20	9.95	100.00

* = animals with unilateral or bilateral cryptorchidism; N = number of animals; ($\chi^2 = 4.36$; $P < 0.05$).

are located on different chromosomes in humans and rats (Ferlin *et al.*, 2008; Kojima *et al.*, 2009; Zhao, Du and Rothschild, 2010). On the other hand, the hypothesis of a pleiotropic action of the RXFP2 gene can be raised since this gene has been associated with cryptorchidism in dogs, rats, and humans (Zimmermann *et al.*, 1999; Foresta and Ferlin, 2004; Yuan *et al.*, 2006; El Houate *et al.*, 2007; Feng *et al.*, 2009; Zhao, Du and Rothschild, 2010) and with the horn phenotype on chromosome 10 in sheep (Johnston *et al.*, 2011). Another possibility is epistatic interaction between the RXFP2 and INSL3 genes, in which failure in the interaction of the INSL3 product with the product of RXFP2 results in problems of testicular descent (Kumagai *et al.*, 2002; Foresta and Ferlin, 2004; Ferlin *et al.*, 2008; Yuan *et al.*, 2010).

The reduction in the number of animals available for selection increased the probability of an animal to be chosen as a breeding animal. As a consequence, the intensity of selection on birth weight for males and females was reduced. This reduction in selection intensity was much greater for females than for males, since the number of females necessary for replacement is higher than the number of males. Fewer males are necessary for breeding because of the higher reproductive rate and the selection intensity is therefore generally greater for males. The intensity of selection is one of the main factors that influence genetic gain. As the proportion of selected animals increases, the intensity of selection, and consequently the genetic gain, decreases (Falconer and Mackay, 1996).

A loss in genetic gain was observed when animals were culled due to one or more of the racial characteristics evaluated in this study. The loss in genetic gain for birth weight was small when the animals were culled due to coat colour and presence of horns. This finding can be explained by the low frequency of animals with a black coat or horns. Once the possible genetic association between polled and cryptorchidism is confirmed, the impact of selection against the presence of horns will prove to be much higher than that estimated in this study.

These results highlight that the high culling rate of animals due to the lack of compliance with the official racial pattern impairs genetic progress of the flock because there is a risk of not achieving the minimum number of animals necessary for annual replacement in the flock.

The results obtained in this study demonstrate that the selection of animals based on racial pattern causes losses in the genetic gain that would be possible when selection for birth weight is performed. These results were somehow expected since the true intensity of selection and consequently the genetic gain decrease drastically when other traits that are not part of the selection objective of a genetic breeding program are considered (Van der Werf, 2006). Thus, similar losses in genetic gain are expected for other traits of economic interest.

The establishment of an official racial pattern is a fundamental tool to permit a trained observer to identify animals that are products of crosses with other breeds and to avoid their decharacterization. On the other hand, this racial pattern should not be excessively restrictive. Otherwise, the possibility of genetic improvement of a breed would be reduced and the breed will become unfeasible in the long term as an alternative for use in commercial production systems.

In the case of the Morada Nova breed, the need for readaptation of the official racial pattern seems to be evident in an attempt to reduce culling due to the lack of compliance with this pattern and to permit co-evolution of the breed with the production system(s). In this respect, the present results indicate that the most urgent step is flexibilization of the requirement of dark muzzles and hooves. In parallel, further studies are fundamental to elucidate the mechanisms of inheritance of coat colour and particularly the association of polled with cryptorchidism.

The selection of Morada Nova sheep based on racial pattern has caused losses in the genetic gain for productive traits such as birth weight. Readaptation of the official racial pattern established for Morada Nova sheep is necessary so that the racial pattern is achieved and an adequate number of animals will be available for selection.

Acknowledgement

The authors acknowledge the financial support from Bank of Northeast of Brazil (BNB), the Cearense Foundation for the Support of Scientific and Technological Development (FUNCAP) and Brazilian Association of Morada Nova Sheep (ABMOVA) for providing the data.

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Animal Genetic Resources, 2016, 58, 83–89. © Food and Agriculture Organization of the United Nations, 2016
doi:10.1017/S2078633616000011

Technical-economical aspects of the Alcarreña sheep farms in Spain and characterization of their meat products

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Summary

Alcarreña is an endangered Spanish sheep breed (8 009 breeding animals) characterized by its adaptation to a particularly harsh environment and by having a sustainable pasture-based, small-scale, production model. The first objective of this study was to identify the technical-economic aspects of the Alcarreña farms, based on information obtained from surveys. The second objective was to quantify the influence of slaughter weight (12, 19 and 23 kg) on the sensory characteristics of the lamb meat. The mean age of the Alcarreña sheep farmers was lower than the average age of Spanish sheep farmers; however, generational renewal is not assured because most of the farmers' children were still in school. Mean flock size was higher than the average Spanish sheep flock. Alcarreña sheep were reared under an extensive management system, grazed year-round and had a reproductive schedule of three lambings within 2 years. The carcass and meat qualities of the 12 and 19 kg lambs did not differ significantly, although the lightest lambs had the softest meat and the clearest subcutaneous fat. The most important differences between the lighter lambs and the 23-kg lambs were in meat and fat colour and lipid composition. Among the sensorial characteristics, the 19-kg lambs had the lowest meat fibrosity, and meat colour and slaughter weight were negatively correlated.

Keywords: *Alcarreña, sheep, surveys, lamb, meat*

Résumé

Alcarreña est une race en voie de disparition espagnol de moutons (8009 tetes) caractérisé par son adaptation à un environnement particulièrement rude et en ayant un modèle de production durable. Le premier objectif de cette étude était d'identifier les caractéristiques technico-économiques sur la base d'informations obtenues à partir des fermes. Le deuxième objectif était de quantifier l'influence du poids d'abattage (12, 19, et 23 kg) sur les caractéristiques sensorielles de la viande d'agneau. L'âge moyen des éleveurs de moutons Alcarreña était inférieure à la moyenne d'âge des éleveurs de moutons espagnols. Cependant, le renouvellement des générations est pas assurée parce que la plupart des enfants de paysans étaient encore à l'école. Moyenne affluent taille était supérieur à la moyenne troupeau de moutons espagnol. Alcarreña moutons ont été élevés dans un système de gestion étendu, effleuré l'année, et a eu un calendrier de reproduction de trois agnelages en deux ans. La carcasse et de la viande qualités des 12 kg et 19 kg agneaux ne diffèrent pas significativement, bien que les agneaux légers avaient le plus doux de la viande et la plus claire de graisse sous-cutané. Les différences les plus importantes entre les agneaux légers et les agneaux de 23 kg ont été dans la viande et la couleur de la graisse et de la composition lipidique. Parmi les caractéristiques sensorielles, les agneaux de 19 kg avaient la fibrosité de la viande le plus bas, et la couleur de la viande et le poids d'abattage ont été corrélées négativement.

Mots-clés: *Alcarreña, moutons, enquêtes, agneau, viande*

Resumen

La Alcarreña es una raza ovina española en peligro de extinción (8009 reproductores), caracterizada por su adaptación a un entorno hostil y por tener un modelo de producción sostenible. El primer objetivo de este estudio fue obtener información de sus ganaderías para determinar sus características técnico-económicas. El segundo objetivo fue determinar la influencia del peso al sacrificio sobre las características sensoriales de la carne de cordero de la raza Alcarreña. Se han comparado tres pesos de sacrificio (12, 19 y 23 kg). La edad media de los ganaderos está por debajo de los valores españoles promedio, aunque esto no significa que la renovación generacional aún está asegurada, ya que la mayoría de los hijos todavía están en la escuela. El censo media es superior a la media española. Las ovejas Alcarreña se crían bajo un sistema extensivo, con pastoreo conducido durante todo el año y con tres partos en dos años. Los estudios de calidad de la canal y de la carne han revelado que la diferencia entre 12 y 19 kg no es importante, aunque los corderos ligeros son más blandos, con una grasa subcutánea más clara. Las diferencias más importantes con los corderos de 23 kg

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son el color de la carne y de la grasa y la composición lipídica. En cuanto a las características sensoriales, sólo se observó una disminución de la fibrosidad de carne en los animales de 19 kg, y una disminución del color a mayores pesos de sacrificio.

Palabras clave: *Alcarreña, ovino, encuestas, cordero, carne*

Submitted 7 October 2015; accepted 7 January 2016

Introduction

The Alcarreña sheep is an endangered Spanish breed, according to the Official Catalogue of Livestock Breeds of Spain, and is included in the Domestic Animal Diversity Information System (DAD-IS, 2016). The most recent census documented 8 009 breeding animals (7 714 ewes and 295 rams; MAGRAMA, 2014). The breed originated in the Alcarria region (Cuenca and Guadalajara provinces) in Castilla-La Mancha. Like many other breeds of its type, it is characterized by its adaptation to a particularly harsh environment and by having a sustainable, pasture-based, small-scale, production model. To motivate farmers to preserve the breed, the Alcarreña Sheep Breeders Association (AGRAL) was founded in 1998, and a Stud Book was created in 2005. In 2011, the Conservation Program of the Alcarreña Sheep breed was approved; however, the production system of the breed has not been fully characterized and field surveys are necessary to increase the understanding of their technical and economic farm characteristics.

In the Spanish market, lamb is a traditional product that, in many cases, is protected by some Protected Geographical Indications (PGI) such as “Cordero de Extremadura”, “Navarra”, “Manchego”, or “Ternasco de Aragón” (MAGRAMA, 2015). Within those PGIs, consumers can find two types of products: those that have carcass weights between 5 and 8 kg (suckling lambs), and those that have carcass weights between 8 and 16 kg (weaned-finished lambs). When carcass weights exceed the maximums permitted, especially, for suckling lambs the meat has held less appeal to Spanish consumers. Although studies have shown that the reduction in consumer appeal is not a function of meat quality, heavy carcasses can increase the productivity of the farms (Sañudo *et al.*, 1996); however, breed has a strong influence on those results (Martínez-Cerezo *et al.*, 2005a). Therefore, it is necessary to quantify the influence of slaughter weight on consumer preferences for individual breeds.

In 2009, the Alcarreña meat breed received the distinction of “Marca de Calidad Colectiva” (Mark of Collective Quality), which includes two categories: Alcarria suckling lamb (carcass weight between 4.5 and 8 kg) and Alcarria lamb (carcass weight between 10 and 15 kg). Although the breed standard has been defined, no studies have provided a full standardization of the breed’s meat products.

The first objective of this study was to identify the technical-economic features of the farms (e.g., flock size, social structure among the farmers, facilities, feeding and reproductive strategies of the Alcarreña breed based on information obtained from all of the farms that belonged to AGRAL. The second objective was to quantify the effects of slaughter weight on the sensory characteristics of Alcarreña lamb meat.

Material and methods

Surveys

Surveys, which were conducted with all of the farmers ($n = 12$) who belonged to AGRAL, included the following data: identity of the farm, social (age of the farmer, responsibilities of family members, generational continuity, when livestock activity rearing began and economic data (labour, other activities), subjective opinion of the farmer about the Alcarreña breed, and farm characteristics (size, land, agriculture, pasture area, facilities, installations, reproductive management, type of lamb produced and percentage replacement).

Animals

Thirty Alcarreña lambs were assigned to one of three groups based on their slaughter weight (12, 19, or 23 kg). The first group was designated “Alcarria suckling lamb” and the other two groups were designated “Alcarria lamb”. After lambs were slaughtered at a local abattoir and 3 days of maturation, carcasses arrived at the Laboratory of Food Technology of the University of Salamanca. Carcass length and leg and chest circumferences were measured (cm). Samples from the *Longissimus dorsi* (left ribs) between the L1-L6 vertebrae were vacuum packed, and frozen and stored at −20 °C until the analyses. The following physico-chemical characteristics of the carcasses were recorded: pH (pH-meter puncture HANNA HI 99163), fat cover and meat colour between the 8th and 9th vertebrae after 1 h of exposure to air, which was estimated based on the L*a*b* system using a colorimeter (MiniScan XEPlus, Hunter Lab) equipped with a 25-mm measuring head and diffuse/8° optical geometry. CIELab parameters were calculated for the Commission internationale de l’éclairage (CIE) illuminant D_{65} and 10° standard observer conditions. Fat content was measured by extraction in ether (AOAC, 1990), moisture was measured using an infrared moisture analyser (Sartorius MA100) (Lurueña-Martínez *et al.*, 2004), water holding capacity was estimated based on the Grau and Hamm (1953) Technique (as described by Sañudo, Sanchez and Alfonso (1998)), and ash content was measured by incineration in muffle (ISO R-936). For texture analysis, samples were wrapped in foil and cooked on a double grill pan at an internal temperature of 70 °C. Texture analysis was performed on 1-cm^2 cross-section portions using the TX-T2 iplus (Stable Micro Systems) texture analyser equipped with a Warner-Bratzler probe (WBSF). Fatty acid content of the subcutaneous fat tissue was extracted with methanol/chloroform (Folch, Lees and Sloane Stanley, 1957). The extractions were subjected to methylation in a basic medium using potassium hydroxide (KOH) in anhydrous methanol (Murrieta, Hess and Rule, 2003) and analysed by gas chromatography (GC 6890 N, Agilent Technologies, USA) using an automatic injector and flame ionization detector (FID) detector (Lurueña-Martínez, Vivar-Quintana and Revilla, 2004). The fatty acids were identified based on retention time of fatty acid standards (47885-U Supelco, Sigma-Aldrich, Germany), and a mixture of CLA (0563 Sigma-Aldrich, Germany). Fatty acid contents (SFA: total saturated fatty acids, MFA: total monounsaturated fatty acids, PFA: total polyunsaturated fatty acids, CLA: total conjugated linoleic acid) were calculated based on chromatogram peak areas and were expressed as g per 100 g total fatty acid methyl esters.

Sensory analyses were performed by a trained analytical taste panel. Samples were slow-thawed at 4–6 °C before being cut into 1-cm-thick portions. One portion was used for the sensory analysis of raw meat and the other portion was wrapped in foil and cooked on a double grill pan to an internal temperature of 70 °C. After the recruitment, selection and training of the participants, the taste panel comprised ten individuals who were trained to perform Quantitative Descriptive Analysis. Members evaluated the samples based on a list of descriptors that had been chosen and defined during training. The assessments involved five attributes for raw meat and 15 attributes for cooked meat. To establish the range of values of each attribute, we used photographs, and standards for odour, texture and taste. The evaluations were performed based on a 9-point structured scale in which 1 and 9 represented the lowest and highest values of the attribute, respectively.

ANOVA and LSD Fisher Tests were used to identify significant differences between groups.

Results and discussion

In our knowledge, this is the first report on the technical characteristics of the farms of the endangered Alcarreña sheep breed, and the first description of the quality of the lamb meat.

Surveys

The average age of the Alcarreña sheep farmers was 52 years, which is similar to the average age of Xisqueta breed farmers (Avellanet, Aranguren-Méndez and Jordana, 2005) and 10 years older than the average age of Manchega breed farmers (Pérez-Guzmán *et al.*, 2002). Eight percent of the Alcarreña sheep farms could guarantee continuation into the next generation, which is less than the proportions reported for Rasa Aragonesa (54 percent; GTE Oviaragón, 2009) and Xisqueta farms (30 percent; Avellanet, 2002). Fifty-eight percent of the Alcarreña sheep farmers had children in school; therefore, they could not be assured that they will have generational renewal, and 33 percent confirmed that they did not have generational renewal. Mean time spent in the sheep industry by Alcarreña sheep farmers was 22 years, and most of them had inherited the farm from their parents. Only 17 percent of the farmers had owned sheep for <10 years. About 75 percent of the farmers received on-farm (mostly intermittent) support by family members, typically, either during peak seasons (lambing periods) or at the time of crop harvest (92 percent of the farms included croplands (cereals, lavender, sunflower, olive trees) and some were involved in producing wicker (a traditional industry in the area). Furthermore, some were involved in the service sector (bar, butcher, or kiosk). Two of the farmers were veterinarians.

All of the farmers in the study have always had Alcarreña sheep, and they valued its hardiness, productivity and the small size of the breed, which is considered more manageable and less demanding in terms of food than the other breeds. Another important reason for farmers to maintain the Alcarreña breed is the appeal of EU subsidies for the maintenance of pure indigenous breeds that are endangered, which was, for 75 percent of the farmers, the most important reason for maintaining the breed. Sixty-seven percent of the farmers were satisfied with the Alcarreña breed and did not indicate any detractions, although 25 percent cited low performance and 17 percent noted low prolificacy as detractions.

All of the farms were in the Alcarria region and, with the exception of one farm in the province of Guadalajara, the farms were in the province of Cuenca. On an average, the farms were 1 464 hectares, most of which was common pastures (mean = 1 315 ha). On an average, 10.2 percent of each farm were crops.

The average area of all facilities on a farm was 1 770 m^2, and an average of 1.82 buildings/farms. Fifty-four percent of the farms received electricity from generators, 29 percent received power from the electrical grid, 8 percent had both sources of power on their farms, 8 percent had solar panels and 8 percent had no electricity on their farms. All of the farms had water (29 percent had running water and 71 percent receive water from springs or other natural sources).

Table 1. Characteristics of the Alcarreña lambs, which were slaughtered at one of three liveweights (mean ± SD).

	12 kg	19 kg	23 kg	Significance
Slaughter age	$47.5^{b} \pm 0.64$	$48.8^{b} \pm 0.64$	$76.5^{a} \pm 0.64$	***
Slaughter weight	$12.8^{c} \pm 0.45$	$18.9^{b} \pm 0.45$	$23.7^{a} \pm 0.85$	***
Average daily gain (g)	$186^{c} \pm 0.02$	$307^{a} \pm 0.03$	$258^{b} \pm 0.05$	***
Hot carcass weight (kg)	$6.1^{c} \pm 0.28$	$9.3^{b} \pm 0.28$	$11.3^{a} \pm 0.28$	***
Dressing percentage (%)	47 ± 4	47 ± 2	47 ± 1	ns
Carcass length (cm)	$53.6^{c} \pm 1.08$	$57.1^{b} \pm 1.08$	$69.4^{a} \pm 1.08$	***
Leg circumference (cm)	$40.4^{b} \pm 0.76$	$50.7^{a} \pm 0.76$	$49.6^{a} \pm 0.76$	***
Chest circumference (cm)	$47.7^{c} \pm 0.71$	$54.4^{b} \pm 0.71$	$57.7^{a} \pm 0.71$	***

ns: not significant differences ($P > 0.05$). ***$P \leq 0.001$. Different letters in the same row: $P < 0.05$.

Mean flock size was 827 heads, which was higher than the flock sizes reported for Rasa Aragonesa (GTE Oviaragón, 2009), Manchega (MAGRAMA, 2014), Castellana (Alonso, González and Redondo, 2001) and Ripollesa (Milán and Caja, 1999) farms. The average number of rams per flock was 23, which corresponded to a ram/ewe ratio of 1:36. Only 25 percent of the farms had flocks that were entirely Alcarreña sheep. The average "per capita" total forage area was 1.72 ha/sheep and 2.31 m^2/sheep in the facilities. On an average, each farm had 1.83 workers and 464 sheep/workers. Eighty-three percent of the farms had employees, which was a higher proportion than that reported among Rasa Aragonesa farms (19 percent; GTE Oviaragón, 2009).

On 25 percent of the farms, rams were kept with ewes year round. Most (75 percent) of the Alcarreña sheep farms used a reproduction system that involved three lambings within 2 years, which was common on Castellana (90 percent; Alonso, González and Redondo, 2001), Segureña (78 percent; Marín-Bernal, Navarro-Ríos and Puntas, 2008) and Xisqueta (72 percent; Avellanet, Aranguren-Méndez and Jordana, 2005) sheep farms. Hormonal treatments were used on 25 percent of the farms (progestagen sponges or melatonin implants). Mean number of lambing periods per farm was 2.67/year. Lambings were concentrated in June, September and November.

All of the Alcarreña farms used controlled grazing, with weather as the only limiting factor; thus, most of the farms were classified as extensive.

To achieve 100 percent liveweight maintenance requirements, only 17 percent of the farms used food resources produced on the farm. On an average, lambs stayed with their mothers for 42 days, and were weaned at a mean liveweight of 12.9 kg. In Segureña lambs, the average age and weight at weaning is about 50 days and 14.5 kg, respectively (Marín-Bernal, Navarro-Ríos and Puntas, 2008). Weaning occurs rarely on Ripollesa farms before slaughter, and lambs remain housed on farms until they are sold (Milán and Caja, 1999).

Alcarreña lambs are sold as suckling lambs or are fattened on the farm or in external feedlots. Mean age and liveweight at sale was 52.67 days and 17.42 kg (range 11–27 kg), respectively. Mean Spanish lamb weight at sale was 16.09 kg (MAGRAMA, 2014); thus, Alcarreña lambs were sold at a slightly higher weight than the other breeds of Spanish lambs.

On Alcarreña sheep farms, mean replacement was 24 percent/year, and replacements were ewe lambs that were in the best condition on the same farm, with the racial standard of the breed taken into account. The average replacement rate of various breeds of sheep in Spain is 15–20 percent (MAGRAMA, 2014).

Lambs

Cold carcass weights confirmed that the first group of animals in our study corresponded to "Alcarria suckling lamb" and the other two groups corresponded to "Alcarria lamb" (Table 1). With the exception of dressing percentage, the carcass characteristics of the three "weight-based groups" of lambs differed significantly ($P < 0.001$). It is important to note that 12 and 19-kg lambs were the same age at slaughter (Table 1), which is likely due to the genetic variability of the breed. In fact, the genetic improvement scheme of the Alcarreña breed states that daily growth is one of the most important traits to be considered.

Slaughter weight did not have a significant effect on basic physicochemical meat characteristics (Table 2); however slaughter weight and WBSF were significantly correlated; the meat of lambs slaughtered at 19 kg was softer than the meat from lambs in the other two groups, which had the highest cutting forces, and did not differ significantly ($P < 0.01$).

The meat from 23-kg lambs was significantly ($P < 0.05$) less yellow (b*) than was the meat from 12-kg lambs (Table 2). In another study, the meat from lambs fed milk was slightly less yellow than the meat from grazing lambs (Ripoll *et al.*, 2008).

Fat lightness and slaughter weight were significantly ($P <$ 0.05) positively correlated, which might have been related to the decrease in brown adipocytes as animals grow (Cannon and Nedergaard, 2004), and to a change in diet from milk to grazing and concentrates (Ripoll *et al.*, 2008).

Slaughter weight was significantly ($P < 0.001$) negatively correlated with SFA ($P < 0.001$), which resulted in an

Table 2. Mean (±SD) physico-chemical variables of the meat from Alcarreña lambs, which were slaughtered at one of three live weights.

	12 kg	19 kg	23 kg	Significance
Carcass weight (kg)	6.15 ± 0.88	9.34 ± 0.82	11.31 ± 0.99	***
pH	5.59 ± 0.10	5.62 ± 0.06	5.62 ± 0.08	ns
Fat (%)	1.44 ± 0.34	1.67 ± 0.55	1.41 ± 0.24	ns
Moisture (%)	77.34 ± 0.69	77.20 ± 0.80	77.47 ± 0.99	ns
Ash (%)	1.56 ± 0.45	1.69 ± 0.38	1.64 ± 0.42	ns
Protein	19.66 ± 0.50	19.44 ± 0.63	19.48 ± 1.08	ns
WBSF (N)	$55.35^{b} \pm 20.42$	$40.01^{a} \pm 11.21$	$55.01^{b} \pm 14.57$	**
WHC	20.07 ± 2.78	20.13 ± 1.63	19.13 ± 2.11	ns
Muscle colour				
*L**	44.60 ± 2.74	45.14 ± 3.02	43.31 ± 2.69	ns
a*	10.98 ± 1.58	11.19 ± 2.17	11.59 ± 1.40	ns
b*	$13.59^{b} \pm 1.30$	$12.82^{ab} \pm 1.85$	$12.09^{a} \pm 1.34$	*
Fat colour				
*L**	70.79 ± 4.06^{a}	74.83 ± 3.85^{b}	74.22 ± 4.00^{b}	**
a*	4.26 ± 1.99	4.38 ± 2.95	4.68 ± 2.70	ns
b*	14.85 ± 3.45	13.30 ± 4.87	13.08 ± 4.68	ns

ns: not significant differences ($P > 0.05$). *$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$. Different letters in the same row: $P < 0.05$.
WBSF, Warner-Bratzler Shear Force; WHC, water holding capacity.

Table 3. Mean (±SD) concentrations of the fatty acids (g/100 g) of Alcarreña lambs, which were slaughtered at one of three live weights.

	12 kg	19 kg	23 kg	Significance
SFA	$53.90^{b} \pm 6.47$	$51.19^{b} \pm 4.21$	$44.57^{a} \pm 3.23$	***
MFA	$32.40^{a} \pm 6.37$	$35.25^{a} \pm 4.99$	$40.92^{b} \pm 3.03$	***
PFA	4.09 ± 0.57	4.17 ± 0.56	4.58 ± 0.79	ns
CLA	0.86 ± 0.27	0.89 ± 0.17	0.81 ± 0.29	ns
PFA/SFA	$0.07^{a} \pm 0.02$	$0.07^{a} \pm 0.01$	$0.09^{b} \pm 0.03$	**
n-6/n-3	$3.88^{a} \pm 0.91$	$4.76^{a} \pm 2.32$	$9.56^{b} \pm 5.07$	***

ns: not significant differences ($P > 0.05$). **$P \leq 0.01$; ***$P \leq 0.001$. Different letters in the same row: $P < 0.05$.
SFA, total saturated fatty acids; MFA, total monounsaturated fatty acids; PFA, total polyunsaturated fatty acids; CLA, total conjugated linoleic acid.

increase in the PUFA/SFA ratio ($P < 0.01$), and significantly positively correlated with MFA (Table 3). CLA and PUFA did not differ significantly between slaughter weights, although the *n*-6/*n*-3 ratio and slaughter weight were significantly ($P < 0.001$) correlated. The lipid profile of the meat from the 23-kg lambs differed significantly from the profiles of the lighter lambs, mainly because of a change from a milk diet (Lurueña *et al.*, 2010) to a diet of concentrates and forage (Santos-Silva, Bessa and Santos-Silva, 2002). The lipid profiles of the 12 and 19-kg lambs did not differ significantly.

The colour of the raw meat differed significantly ($P < 0.05$) among the slaughter-weight groups; specifically, the meat from the 19-kg lambs was slightly darker than the meat from the 23-kg lambs, but indistinguishable from the meat from the 12-kg lambs (Table 4), probably because of the lower intramuscular fat content of the meat, which was detected by the panelists.

The colour intensity of the cooked meat and slaughter weight were negatively correlated; specifically, the meat from the 19 and 23-kg lambs were significantly ($P < 0.01$) clearer than the meat from the 12-kg lambs (Table 5). Those results parallel the assessments of instrumental fat colour, but not those of the appearance of the raw meat, and are unlike to those of other studies (Sañudo *et al.*, 1996) that showed a correlation between raw meat colour and slaughter weight. The hardness and fibrosity of the meat from the 19-kg lambs was significantly ($P < 0.001$) lower than that of the meat from the

Table 4. Mean (±SD) values of the variables of the qualities of the raw meat from Alcarreña lambs, which were slaughtered at one of three live weights.

	12 kg	19 kg	23 kg	Significance
Appearance				
Pink colour	$6.67^{ab} \pm 0.82$	$7.83^{b} \pm 0.98$	$6.00^{a} \pm 1.26$	*
Fat content	3.67 ± 0.52	2.83 ± 0.41	3.33 ± 1.03	ns
Fibre content	3.00 ± 0.89	2.33 ± 0.82	3.33 ± 1.21	ns
Odour				
Intensity	4.50 ± 1.05	3.50 ± 1.05	4.17 ± 1.17	ns
Anomalous	1.50 ± 0.84	1.17 ± 0.41	1.17 ± 0.41	ns

ns: not significant differences ($P > 0.05$). *$P \leq 0.05$. Different letters in the same row: $P < 0.05$.

Table 5. Mean (±SD) values of the variables of the sensory properties of the cooked meat from Alcarreña lambs, which were slaughtered at one of three live weights

	12 kg	19 kg	23 kg	Significance
Aspect				
Brown colour	$5.00^b \pm 1.10$	$3.67^a \pm 1.21$	$2.83^a \pm 0.75$	**
Fat content	2.83 ± 0.75	2.17 ± 0.75	2.17 ± 0.75	ns
Fibrosity	2.83 ± 0.98	3.17 ± 0.75	2.50 ± 0.55	ns
Odour				
Intensity	3.83 ± 1.83	3.83 ± 1.17	3.67 ± 1.03	ns
Anomalous	1.33 ± 0.52	1.33 ± 0.52	1.67 ± 0.82	ns
Texture				
Hardness	4.33 ± 0.82	4.00 ± 1.55	4.67 ± 1.51	ns
Chewiness	4.50 ± 1.22	5.00 ± 1.10	5.83 ± 1.72	ns
Fibrosity	$4.83^a \pm 0.41$	$4.33^a \pm 1.37$	$6.83^b \pm 0.41$	***
Juiciness	2.83 ± 0.75	3.50 ± 1.22	2.33 ± 0.52	ns
Fat sensation	2.50 ± 1.05	2.67 ± 1.03	2.17 ± 0.75	ns
Flavour				
Intensity	3.33 ± 0.52	4.67 ± 1.37	4.67 ± 1.37	ns
Acid	1.67 ± 0.82	2.17 ± 0.98	2.17 ± 0.75	ns
Suckling lamb	2.67 ± 0.82	3.50 ± 1.05	4.00 ± 1.26	ns
Others				
Residue in throat	2.67 ± 0.82	3.17 ± 0.75	3.67 ± 0.82	ns

ns: not significant differences ($P > 0.05$). **$P \leq 0.01$; ***$P \leq 0.001$. Different letters in the same row: $P < 0.05$.

23-kg lambs, but not significantly different from that of the 12-kg lambs. Those results parallel the results of the instrumental texture evaluation, which indicated that the WBSF was lowest in the 19-kg group, but they differ from other studies (Sañudo *et al.*, 1996), which reported an increase in hardness with slaughter weight. Flavour characteristics did not differ significantly among the slaughter-weight groups, although they tended to increase with slaughter weight, which has been reported elsewhere (Jeremiah, Tong and Gibson, 1998; Martínez-Cerezo *et al.*, 2005a, b), because of the changes in the lipid profile (Sink, 1979).

Conclusions

In conclusion, Alcarreña sheep breed farms were characterized by a mean age of their owners that was below the average for Spanish sheep farms in general, although generational renewal was not assured on most of the Alcarreña farms. Alcarreña sheep flocks were larger than the average size of Spanish sheep flocks. Farmers emphasized the positive qualities of the breed, which is reared under an extensive management system, permitted to graze year round, and follows a three-lambings-in-2-years reproductive calendar. The analyses of carcass and meat qualities showed that the differences between the 12 and 19-kg slaughter weights were minor, although the meat from the 19-kg lambs was softer and had clearer fat. Meat and fat colours and lipid composition were the most important distinguishing characteristics of the meat from the 23-kg lambs. Meat fibrosity was lowest in the 19-kg lambs, and colour and slaughter weight were inversely correlated.

Acknowledgements

We thank the farmers of the Alcarreña Sheep Breeders Association (AGRAL) for their collaboration, and Bruce MacWhirter for the English revision of the article.

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Animal Genetic Resources, 2016, 58, 91–100. © Food and Agriculture Organization of the United Nations, 2016
doi:10.1017/S2078633616000059

Between- and within-breed morphological variability in Moroccan sheep breeds

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Summary

The objective of this study was a morphological characterization of five Moroccan sheep breeds (Béni Guil, Boujaâd, D'man, Sardi and Timahdite) to assess between- and within-breed variability using multivariate analyses. Fourteen morphological measurements were collected on 876 adult animals of both sexes in 98 different flocks located in 22 geographic localities of five breeds. The multiple analysis of variance revealed that significant morphological differences existed between breeds. The overall proportion of total variance due to between-breed component was 28.3 percent. The factor analysis revealed three factors accounting for 50.1, 11.8 and 7.54 percent of total variance. The first factor had high loadings for variables relating to body size, whilst the second factor had high association with traits reflecting tail length and ear size. The third factor had high loadings for wool trait. The squared Mahalanobis distance between the five sheep breeds were highly significant ($P < 0.001$). The largest morphological divergence was shown between Béni Guil and Sardi breeds (23.5) and the smallest one was between Boujaâd and Sardi breeds (3.54). The discriminant functions clearly discriminated and assigned 94.4 percent of Béni Guil, 79.7 of Boujaâd, 88.5 percent of D'man, 86.7 of Sardi and 80.1 percent of Timahdite sheep into their breed of origin. Overall morphological differences observed within-breeds were due for 18.1 percent to geographic locality and for 20.7 percent to flock management. It was concluded that the information reported in this study will be the basis for the establishment of characterization and selection strategies for Moroccan sheep.

Keywords: *breed differentiation, discriminant analysis, Mahalanobis distance, Moroccan sheep, morphological traits*

Résumé

L'objectif de cette étude a été de caractériser morphologiquement cinq races ovines du Maroc (Béni Guil, Boujaâd, D'man, Sardi et Timahdite) afin de déterminer la variabilité intra- et inter-raciale avec des analyses multivariées. Quatorze mesures morphologiques ont été prises sur un total de 876 animaux adultes des deux sexes de 98 troupeaux différents des cinq races situés dans 22 emplacements géographiques. L'analyse multivariée de la variance a décelé des différences morphologiques significatives entre les races. La variance inter-raciale a représenté 28,3 pour cent de la variance totale. L'analyse factorielle a signalé trois facteurs expliquant 50,1, 11,8 et 7,54 pour cent de la variance totale. Des variables liées à la taille corporelle ont eu une grande influence sur le premier facteur alors que le deuxième facteur a été très en rapport avec des caractères tels que la longueur de la queue et la longueur des oreilles. Le troisième facteur a été lié à la production lainière. Las distances carrées de Mahalanobis entre les cinq races ovines ont été très significatives ($P < 0.001$). La plus grande divergence morphologique a été notée entre les races Béni Guil et Sardi (23,5), alors que la plus faible divergence a été observée entre les races Boujaâd et Sardi (3,54). Les fonctions discriminantes ont bien fait les distinctions, vu qu'elles ont assigné 94,4 pour cent des moutons Béni Guil, le 79,7 pour cent des moutons Boujaâd, le 88,5 pour cent des moutons D'man, le 86,7 pour cent des moutons Sardi et le 80,1 pour cent des moutons Timahdite à leur race correspondante. Les différences morphologiques observées au sein des races ont été dues à 18,1 pour cent à l'emplacement géographique et à 20,7 pour cent aux pratiques d'élevage. En conclusion, les informations obtenues dans cette étude fournissent la base pour la préparation de stratégies de caractérisation et de sélection des ovins du Maroc.

Mots-clés: *différentiation raciale, analyse discriminante, distance de Mahalanobis, caractères morphologiques, ovins du Maroc*

Resumen

Este estudio tuvo por objetivo caracterizar morfológicamente cinco razas ovinas marroquíes (Béni Guil, Boujaâd, D'man, Sardi y Timahdite) con el fin de determinar, empleando para ello análisis multivariantes, la variabilidad intra- e interracial. Se tomaron catorce medidas morfológicas sobre un total de 876 animales adultos de ambos sexos en 98 rebaños diferentes de las cinco razas situados en 22 ubicaciones geográficas. El análisis multivariante de la varianza arrojó diferencias morfológicas significativas entre las razas. La varianza interracial supuso un 28,3 por ciento de la varianza total. El análisis factorial señaló tres factores que daban cuenta del 50,1 por ciento, el 11,8 por ciento y el 7,54 por ciento de la varianza total. Sobre el primer factor tenían un gran peso variables relacionadas con el tamaño corporal, mientras que el segundo factor estaba muy vinculado a rasgos como la longitud de la cola y el tamaño de las orejas. El tercer factor guardaba relación con el carácter lanero. Las distancias cuadradas de Mahalanobis entre las cinco razas ovinas fueron

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muy significativas ($P < 0.001$). La mayor divergencia morfológica se observó entre las razas Béni Guil y Sardi (23,5), mientras que la menor divergencia se dio entre las razas Boujaâd y Sardi (3,54). Las funciones discriminantes discernieron correctamente, asignando el 94,4 por ciento de las ovejas Béni Guil, el 79,7 por ciento de las ovejas Boujaâd, el 88,5 por ciento de las ovejas D'man, el 86,7 por ciento de las ovejas Sardi y el 80,1 por ciento de las ovejas Timahdite a sus respectivas razas. Las diferencias morfológicas observadas dentro de las razas se debieron en un 18,1 por ciento a la ubicación geográfica y en un 20,7 por ciento al manejo del rebaño. Se concluye que la información obtenida en este estudio sienta la base para el diseño de estrategias de caracterización y selección de las ovejas marroquíes.

Palabras clave: *ovejas marroquíes, rasgos morfológicos, distancia de Mahalanobis, análisis discriminante, diferenciación racial*

Submitted 8 September 2015; accepted 10 March 2016

Introduction

The population of sheep in Morocco is currently estimated at 17.1 million. According to Mason (1969), it is composed by some twenty different breeds that have ability to tolerate harsh climates, resistance to prevailing diseases, good recovery capacity from drought, efficient utilization of limited feed resources, suitability to extensive systems, etc. At present, the most important breeds are Sardi, Timahdite, Béni Guil, D'man and Boujaâd. These breeds were phenotypically characterized and their breed standards were established since the beginning of 1980s when the sheep plan, called "Plan Moutonnier" (MARA, 1980), was published. At that time, the breeding areas of these breeds were delimited and included only few thousands of animals. With the development of the breeders' association, named "Association Nationale Ovine et Caprine, ANOC", several other breeder groups were created, and breeding areas became very large and included several thousands of animals that were often different from those that were used initially for establishing breed standards. Moreover, Eyraud (1934) reported that some Moroccan sheep breeds were formed by grouping some subpopulations that existed in the past within the same breeding area. However, this hypothetical presence of subpopulations within some local breeds has never been tested. If true, important consequences may occur on selection and even conservation programmes of these breeds.

The first step of sheep characterization is the population identification based on morphological measurements, which allows the knowledge of sheep variability (Gizaw *et al.*, 2007; Traoré *et al.*, 2008; Esquivelzeta *et al.*, 2011). Several researchers (Kunene *et al.*, 2007; Carneiro *et al.*, 2010; Birteeb *et al.*, 2013; Mavule *et al.*, 2013; Yunusa *et al.*, 2013) have used body measurements to characterize sheep breeds, to assess between- and within-breed variability and to discriminate different populations. In Morocco, multivariate analyses of morphological traits were never reported in sheep; information was mainly focused on the assessment of production and reproduction performances (Boujenane, 2006). Thus, in order to ensure proper utilization and conservation of Moroccan local breeds, it is necessary to evaluate genetic variation that exists within and among them.

The objectives of this study were to characterize Moroccan local sheep breeds and to assess the between- and within-breed variability of morphological traits using multivariate analyses. Results obtained from this study would provide information useful for updating breed standards both in magnitude and variability and to differentiate between the breeds.

Materials and methods

Studied breeds

The study was carried out on Béni Guil, Boujaâd, D'man, Sardi and Timahdite breeds that are the most important Moroccan local sheep breeds owing to their high number and extended breeding areas. All of them are thin-tailed and rams have fairly well developed spiral horns, except those of D'man breed that are polled (Boujenane, 2005). The breeding areas of Béni Guil, Boujaâd, D'man, Sardi and Timahdite are located in eastern hills, central hills, southeastern oases, central hills and Middle Atlas Mountains of Morocco, respectively. The Béni Guil breed has a regular shape, short neck, brown face and legs and white fleece. The Boujaâd sheep have white to yellowish face with a white fleece, robust bone structure and strong head. The D'man breed has a fleece that is characteristically entirely black, although some animals are brown, white or various combinations of two or all three colours. The bone structure is fine and the head is narrow. The tail is long and usually extends below the hocks. The Sardi breed has animals with white head and black spots around the nose, mouth and eyes. The body fleece is white and the legs are bare. The Timahdite breed has brown face, white legs and fleece. These breeds are described as medium-sized and are reared mainly for meat, although the D'man is valued for its exceptional reproductive characteristics. They are well adapted to local environmental conditions.

Data collection

A total of 876 sheep showing good body condition and meeting the phenotypic standards, established by the

Table 1. Numbers of measured animals per breed, dentition and sex[1].

Dentition	Béni Guil		Boujaâd		D'man		Sardi		Timahdite	
	F	M	F	M	F	M	F	M	F	M
Four permanent incisors	35	6	38	9	33	3	47	10	49	16
Six permanent incisors	40	4	32	10	35	7	38	6	78	15
Eight permanent incisors	53	5	42	7	66	4	62	16	97	13
Sub-total	128	15	112	26	134	14	147	32	224	44
Total	143		138		148		179		268	

[1]F, female; M, male.

"Association Nationale Ovine et Caprine" (ANOC), were used for the study. This sample included 143 Béni Guil, 138 Boujaâd, 148 D'man, 179 Sardi and 268 Timahdite of both sexes. For the purpose of uniformed comparison, only adult animals, i.e. having 4, 6 or 8 permanent incisors (i.e. more than 2 years old) were considered. However, pregnant ewes were excluded from sampling, as pregnancy may affect body weight (BW) and some other morphological measurements. The number of sheep by breed, sex and dentition is presented in Table 1. The high number of females is because they were retained by farmers for reproduction, while the males were very often sold. In each breeding area, farmers with sheep were randomly selected. Moreover, for the sake of large geographic and management variability, only 8–12 animals of both sexes and of different ages were randomly selected in each flock. At the end, a total of 98 flocks (12 Béni Guil, 10 Boujaâd, 15 D'man, 23 Sardi and 38 Timahdite) were visited. These flocks were located in 3, 5, 2, 5 and 7 geographic localities covering a wide range of environments of breeding areas of Béni Guil, Boujaâd, D'man, Sardi and Timahdite breeds, respectively.

In general, the sheep were exploited either extensively or semi-intensively with little supplementary feeding. Except the D'man breed that is indoors all year, the other breeds grazed during the day on natural pastures, low-grade forage or stubbles. They were housed throughout the night in constructed pens or under the open sky with a fenced enclosure made of bushes. Animals were vaccinated against enterotoxaemia and treated against endoparasites.

Studied traits

Morphological measures taken on each animal were those advocated by the FAO for breed characterization according to the DAD-IS program (FAO, 2013). These were body weight (BW), body length (BL, distance from the point of the shoulder to the pin bone), heart girth (HG, perimeter of the chest just behind the front legs and withers), withers height (WH, height from the withers to the ground), chest depth (CD, distance from the brisket between the front legs to withers), chest width (CW, maximum intercostals diameter, just behind the elbows), rump width (RW, maximum distance between left and right hurls), cannon circumference (CC, smallest circumference of the cannon bone of foreleg), head length (HL, frontal distance from poll to the lower lip), head width (HW, maximum distance between zygomatic arches), ear length (EL, distance from the base to the tip of the ear along the dorsal surface), ear width (EW, maximum distance at the middle of the ear), tail length (TL, distance from the tail droop to the tip of the tail excluding switch) and wool length (WL, length of wool fibres taken on the flank). All measurements were recorded using flexible tape (with records taken to the nearest cm), except for WH, RW, thorax width and thorax depth that were taken by graduated measuring stick and calibrated wooden calliper, and BW that was measured using an electronic scale. When measured, animals were put on a flat floor with the head held up, while restricting the animal by holding. Morphological measurements were taken from the right side of the animal by the same operator to avoid between-operator variations. These measurements were realized between February 2014 and March 2015, usually early in the morning before grazing or receiving feed in order to avoid undesirable variations due to weight and rumen volume change.

Statistical analyses

The statistical analyses were carried out using the SAS/STAT package (2002). Data were first analysed using MEAN and FREQ procedures to obtain descriptive statistics for morphological traits studied and frequency distribution of animals. The GLM procedure was used to assess the effect of breed on all body measurements through the multivariate three-way analysis of variance fitting a model that included fixed effect of breed (five levels: Béni Guil, Boujaâd, D'man, Sardi and Timahdite), sex (two levels: female and male) and age (three levels: 4, 6 and 8 permanent incisors). Likewise, to study the within-breed morphological variability, the GLM procedure was used to assess the effect of geographic locality on all body measurements of each breed through the multivariate analysis of variance fitting a model that included fixed effect of locality (from 2 to 5 localities according to the breed), sex (two levels: female and male) and age (three levels: 4, 6 and 8 permanent incisors) and random effect of flock nested within locality. After computing linear contrasts between the different localities of each breed, some were not found statistically different ($P > 0.05$) and, hence, the corresponding localities were combined. At the end, instead of 22 geographic localities, only 15 large localities were identified; three for Béni Guil (Aïn Béni Mathar, Outat Lhaj and Tendrara), three for Boujaâd (Boujaâd, Chougrane and Rouached), two for D'man (Tafilalet and Tinghir), four for Sardi (Béni Meskine, Béni Moussa, Rhamna and Sraghna) and three for Timahdite (Timahdite, Rhoualem and Khénifra). To assess the between-breed morphological variability, the PROC VARCOMP was applied by fitting the previous model that included breed as random effect. Likewise, to assess geographic locality and flock management contributions to within-breed variability, the VARCOMP procedure was used by fitting the previous model that included locality and flock nested within locality as random effects. To obtain an approximate overall multivariate variance component, locality and flock variance components for all traits were then averaged. The FACTOR procedure was used to perform factor analysis, which is a data reduction technique that combines measurements into uncorrelated components. The stepwise discriminant analysis was applied using PROC STEPDISC to identify which morphological traits have more discriminant power than others in separating the five breeds. The significance level applied for retaining or adding a variable was 0.05. The CANDISC procedure was used to perform canonical discriminant analysis for deriving canonical functions, which were linear combinations of body measurements that summarized variation between breeds, and for calculating the squared Mahalanobis distance matrix necessary for the differentiation between-breeds and between-localities within each breed. The DISCRIM procedure was applied to perform discriminant analysis to estimate the proportion of animals that were properly classified into their original breed or geographic locality. The percentage of misclassified animals indicated the degree of admixture between the breeds or geographic localities.

Results

Arithmetic means and coefficients of variation

Arithmetic means and coefficients of variation for body measurements of the five breeds are presented in Table 2. The observed body measurements showed that Moroccan sheep were in general of medium size. Sardi animals had greater morphological measures, except for CW and RW that were greater in Boujaâd sheep. Sardi had tail hanging below hocks (41.4 cm), while Béni Guil had a short tail hanging above hocks (26.0 cm). Also, Sardi and Boujaâd had the widest head (12.0 cm). The overall coefficients of variation of body measurements were 11.3, 10.6, 12.6, 12.7 and 11.2 percent in Béni Guil, Boujaâd, D'man, Sardi and Timahdite, respectively. They were highest for BW (from 26.9 percent in Timahdite to 40.0 percent in Sardi) and lowest for HL (from 4.64 percent in Béni Guil to 7.55 percent in Sardi) and height at withers (from 5.12 percent in Boujaâd to 6.18 percent in Sardi), reflecting great differences in size among the studied animals and indicating some within-breed variability.

Between-breed differences

The multiple analysis of variance for morphological traits revealed that significant differences ($P < 0.001$) existed between breeds. The variance component analysis showed that proportion of total variance attributed to between-breed component represented 16.2, 23.5, 16.3, 60.5, 23.0, 3.80, 22.7, 34.4, 10.5, 23.3, 37.3, 33.0, 24.5 and 66.5 percent for BW, BL, HG, WH, CD, CW, RW, HL, HW, EL, EW, CC, WL and TL, respectively. The Kaiser's Measure of Sampling Adequacy (MSA) value was 0.923. Three factors with eigenvalues greater than 1 were extracted. The factors 1, 2 and 3 accounted for 50.1, 11.8 and 7.54 percent, respectively, totalizing 69.4 percent of the total variance, whilst subsequent factors contributed with less than 6 percent each. The factor 1 assigned positive coefficients to all morphological measurements. The factor 2 gave negative weights to BW, BL, HG, CD, CW, RW, HW and WL, and positive coefficients to all other traits. The factor 3 assigned negative coefficients to BW, BL, HG, CD, HL, HW, CC and TL, and positive coefficients to the remaining traits. The coefficients showed that the highest relative contributions to factors 1, 2 and 3 were BW and HG (0.91), TL (0.60) and WL (0.78), respectively. Variables' communality, which represents the proportion of variance of each of the 14 variables shared by all remaining body measurements, were medium to high. They varied from 0.40 for HW to 0.89 for BW.

The stepwise discriminant analysis showed that all the 14 body measurements were significant ($P < 0.05$), suggesting that all measured variables had a discriminant power in differentiating between sheep breeds. Therefore, all the traits were maintained in the final model. Nevertheless, based on their partial R^2 and F-values ($P < 0.001$), TL, HG, BW, HL, WL and RW had more discriminant power than the others. Their partial R^2 were 0.580 (TL), 0.253 (HG), 0.214 (BW), 0.213 (HL), 0.206 (WL) and 0.157 (RW).

The squared Mahalanobis distances among the five sheep breeds are presented in Figure 1. All pairwise distances were highly significant ($P < 0.001$), indicating that the differences among breeds were important. The largest morphological divergence was shown between Béni Guil and Sardi (23.5) and the smallest one was between Boujaâd and Sardi breeds (3.54). Mahalanobis distance between Béni Guil and Sardi breeds can be qualified as long, those between Boujaâd and Sardi, Boujaâd and Timahdite, and D'man and Timahdite breeds as short, while the remaining distances as intermediate. Figure 1 showed also that the five breeds were classified into three major groups. The first group consisted of Boujaâd and Sardi breeds, the second associated D'man and

Table 2. Arithmetic means (and coefficients of variation in %) for body weight (kg) and other morphological traits (cm) of sheep.

Body measurement[1]	Béni Guil	Boujaâd	D'man	Sardi	Timahdite
Body weight	44.1 (32.5)	57.5 (30.6)	56.5 (29.0)	59.5 (40.0)	53.5 (26.9)
Body length	73.5 (9.38)	79.0 (7.66)	77.2 (7.85)	82.1 (10.2)	77.4 (7.00)
Heart girth	84.0 (9.41)	90.2 (9.10)	87.3 (9.57)	92.6 (10.6)	88.8 (8.19)
Withers height	**69.8** (6.09)	**76.9** (5.12)	**72.8** (6.08)	**80.9** (6.18)	**72.3** (5.97)
Chest depth	31.1 (11.2)	34.7 (9.60)	33.0 (9.09)	35.4 (10.4)	33.2 (10.8)
Chest width	19.3 (15.2)	20.7 (16.4)	18.7 (18.5)	20.6 (18.6)	19.9 (17.8)
Rump width	21.3 (10.6)	23.0 (11.0)	19.4 (11.6)	22.8 (13.9)	21.8 (13.7)
Head length	**24.0** (4.64)	**24.7** (5.46)	**25.1** (5.77)	**26.1** (7.55)	**23.6** (5.00)
Head width	11.5 (6.51)	12.0 (7.50)	11.4 (8.16)	12.0 (8.25)	11.4 (9.56)
Ear length	12.3 (8.11)	13.0 (7.00)	12.7 (7.63)	13.4 (7.39)	12.2 (7.62)
Ear width	**6.78** (8.59)	**7.64** (7.46)	**7.07** (7.39)	**7.90** (7.97)	**7.25** (7.45)
Cannon circumference	8.01 (9.93)	9.02 (10.7)	8.31 (9.71)	9.07 (9.92)	8.30 (9.28)
Wool length	**7.56** (13.6)	**6.70** (10.9)	**5.72** (34.4)	**6.78** (9.92)	**6.17** (13.4)
Tail length	**26.0** (12.5)	**37.8** (9.73)	**35.8** (12.1)	**41.4** (16.7)	**33.9** (13.7)

[1]The most discriminating traits are in bold.

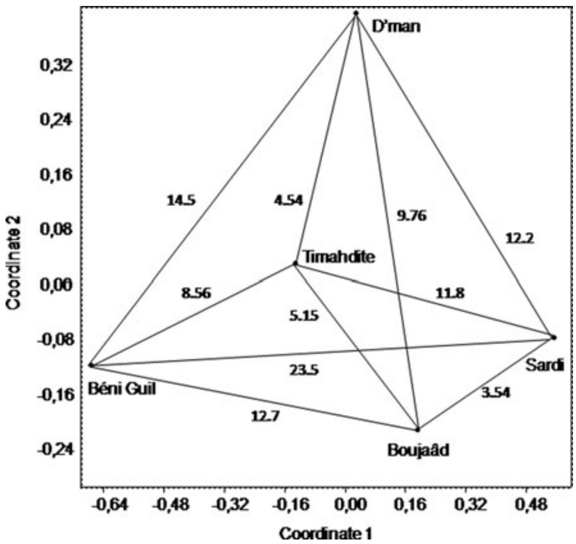

Figure 1. Representation of Mahalanobis distances between the five breeds.

Timahdite breeds, and the third group included the Béni Guil breed.

The canonical discriminant analysis identified four statistically significant ($P < 0.001$) canonical variables CAN1, CAN2, CAN3 and CAN4 that accounted for 57, 30, 11 and 2 percent of total variation, respectively. The canonical correlations were 0.83, 0.74, 0.55 and 0.27 for CAN1, CAN2, CAN3 and CAN4, respectively. The resulting R^2 values ranged from 0.03 for CW to 0.58 for TL, and all traits were significant ($P < 0.001$). Raw canonical coefficients used to derive canonical functions are presented in Table 3. CAN1, CAN2, CAN3 and CAN4 provided the greatest difference between the breed means. The breed means on CAN1 were −2.40, 1.00, 0.06, 2.43 and −0.45 for Béni Guil, Boujaâd, D'man, Sardi and Timahdite, respectively. These values indicated that Sardi breed was best discriminated by CAN1, and differed markedly in body measurements from Béni Guil and Timahdite breeds. Figure 2 showed that CAN1 separated clearly between Béni Guil and Sardi breeds and distinguished relatively well between Béni Guil and Boujaâd breeds. It showed also that the Béni Guil individuals were the most homogeneous and clustered together on the left hand of the CAN1; the Sardi were mainly distributed on the positive values of the CAN1; and the Boujaâd individuals showed an intermediate distribution but clearly close to the Sardi individuals. The second axis separated between the D'man on one hand and Béni Guil, Sardi and Boujaâd breeds on the other hand. It showed that Béni Guil, Sardi and Boujaâd individuals were clustered together on the top of the CAN2; the D'man sheep were mainly distributed on the bottom of the CAN2. The Timahdite individuals were in the middle of both canonical axes. Nevertheless, Figure 2 did not show a clear distinction between breeds.

Table 3. Raw canonical coefficients of canonical discriminant functions.

Variable	CAN1	CAN2	CAN3	CAN4
Body weight	−0.041	−0.1163	0.0137	0.1045
Body length	0.0252	−0.0090	−0.0094	−0.1030
Heart girth	−0.0032	0.0249	−0.0893	−0.2102
Withers height	0.1217	0.1221	0.0789	−0.1184
Chest depth	0.0584	−0.0258	−0.0390	0.1514
Chest width	−0.0650	0.0837	−0.0075	0.0055
Rump width	0.0157	0.3719	−0.1311	0.2907
Head length	0.0759	−0.0313	0.7869	0.0849
Head width	−0.2228	0.2804	−0.0923	−0.0405
Ear length	0.1678	0.1257	0.3928	0.2533
Ear width	0.3494	0.1752	−0.6982	−0.1217
Cannon circumference	0.2696	0.5922	−0.0378	0.2503
Wool length	−0.2041	0.3054	0.2233	−0.0139
Tail length	0.1701	−0.0751	−0.0513	0.0374

The discriminant analysis to determine the percentage of individuals correctly grouped into their own breeds is presented in Table 4. It revealed that 94.4, 79.7, 88.5, 86.7 and 80.2 percent of Béni Guil, Boujaâd, D'man, Sardi and Timahdite sheep, respectively, were correctly

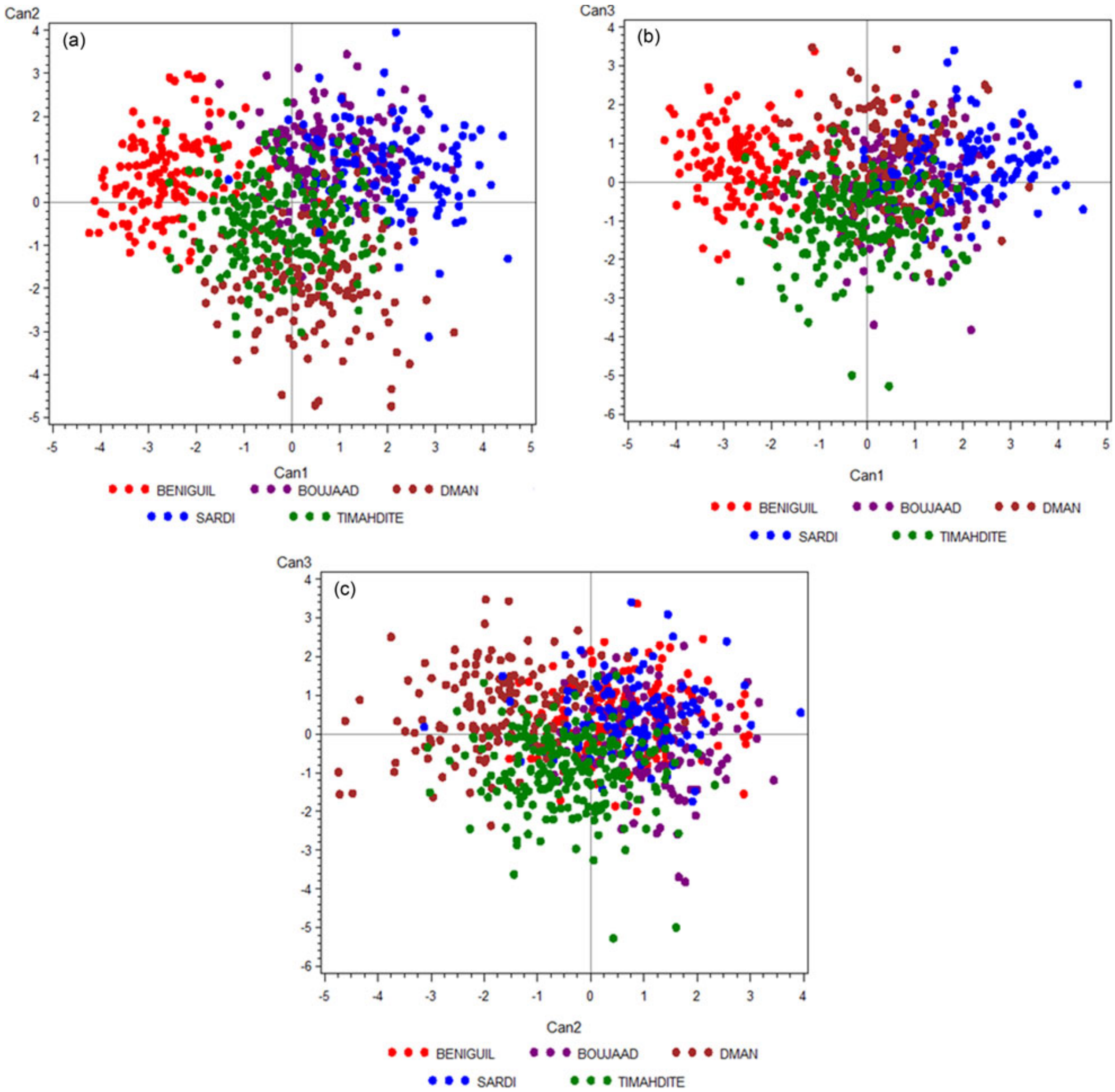

Figure 2. Canonical representation of the Moroccan local sheep breeds using the morphological variables.

classified in their original breed. Most of misclassified Boujaâd individuals were classified as Sardi (12.3 percent) and vice versa (10.0 percent). No misclassified Béni Guil individuals were assigned as Sardi, whereas misclassified Timahdite individuals were classified as Béni Guil (4.74 percent), Boujaâd (6.16 percent) and D'man (7.58 percent).

Table 4. Actual percentages of Moroccan sheep classified into breed.

	Béni Guil	Boujaâd	D'man	Sardi	Timahdite
Béni Guil	94.4	2.10	0.70	0.00	2.80
Boujaâd	0.72	79.7	2.90	12.3	4.35
D'man	0.68	3.38	88.5	2.70	4.73
Sardi	0.83	10.0	0.83	86.7	1.67
Timahdite	4.74	6.16	7.58	1.42	80.1

Within-breed variability

The objective of this study was to check if the heterogeneity of morphological measurements observed within-breeds originated from the presence of different geographic localities or from flock management. The partition of within-breed morphological variability showed that geographic locality and flock management components represented 18.1 and 20.7 percent, respectively for the five breeds, with other sources explaining more than 60 percent (Table 5). The contribution of geographic locality to the

Table 5. Proportions of within-breed variability due to geographic locality and flock management.

Breed	Geographic locality (%)	Flock management (%)	Other sources (%)
Béni Guil	26.8	13.8	59.4
Boujaâd	19.4	11.3	69.3
D'man	6.13	31.1	62.8
Sardi	22.4	21.7	55.9
Timahdite	17.7	30.3	52.0
Overall	18.1	20.7	61.2

within-breed variability varied from 6.13 percent for D'man to 26.8 percent for Béni Guil breeds, whereas that of flock management ranged from 11.3 percent for Boujaâd to 31.1 percent in D'man breeds. For the five breeds, 4, 3, 4, 4 and 4 factors, having eigenvalues >1, were extracted, respectively. These factors were totalizing 69.5, 56.9, 67.1, 59.3 and 57.1 percent of the total variance, respectively. For the five breeds, factor 1 gave positive weights to all body measurements, except WL for which negative coefficient was assigned in Sardi and Timahdite breeds. However, the remaining factors assigned positive as well as negative coefficients to morphological traits. Highest contributions to each of the extracted factors were BW, TL, HW and EW for Béni Guil, BW, EW and WL for Boujaâd, BW, EW, WL and EL for D'man, BW, WL, EL and TL for Sardi, and BW, EW, WL and HW for Timahdite sheep. The representation of individuals in geographic localities on the first two factors (Figure 3) showed that within each breed some localities were clearly differentiated, whereas others exhibited partial overlapping.

The between geographic locality Mahalanobis distances were highly significant ($P < 0.001$), indicating large variation of body measures of animals raised in different localities of the same breed. The highest distances were found between Aïn Béni Mathar and Outat Lhaj localities (11.8) for Béni Guil breed, Chougrane and Boujaâd localities (9.87) for Boujaâd sheep, Beni Meskine and Sraghna localities (8.51) for Sardi breed, and Rhoualem and Timahdite localities (10.1) for Timahdite sheep. For the D'man breed, the distance between Tafilalet and Tinghir localities was 3.33.

Stepwise discriminant analysis showed that the three most discriminating traits between localities were HG, HL and BW for Béni Guil, BW, HL and WH for Boujaâd, CD, HG and TL for D'man, RW, CW and BW for Sardi, and RW, CD and BW for Timahdite sheep. This suggests that taking these traits would be more important in differentiating between geographic localities of each breed.

The discriminant analysis showed that the percentages of individuals correctly classified into their own geographic locality were 84.0, 93.3 and 95.8 percent for Béni Guil, 95.9, 100.0 and 90.9 percent for Boujaâd, 86.5 percent and 95.6 percent for D'man, 93.3, 57.6, 80.0 and 75.6 percent for Sardi, and 86.7, 87.0 and 85.0 percent for Timahdite sheep. Only 8.94, 4.39, 8.96, 23.3 and 21.4 percent of the Béni Guil, Boujaâd, D'man, Sardi and Timahdite animals, respectively, on average, being classified in wrong localities.

Discussion

The mean values for body measurements obtained in the present study would allow for the updating of morphological standards of the five sheep breeds. The most discriminant traits obtained through the canonical analysis were TL, WH, EW, HL and WL. Thus for each breed, the means of these discriminant traits are presented in bold in Table 2. The breed standards used until now in Morocco concerned BW and height at withers only. They were established more than 20 years ago and they did not cover as many animals as the current study. These new breed standards will be very useful for the national commission of the ANOC that selects animals once a year in different flocks around the country. Sardi animals showed a marked superiority for 11 measurements, suggesting better skeletal and muscle development and also indicating that they are suitable for meat production, whilst Béni Guil presented a clear inferiority for eight morphological traits. This may suggest that animals reared semi-intensively (Sardi and Boujaâd breeds) had superior morphological traits compared with those extensively managed (Béni Guil and Timahdite breeds). The D'man breed raised in a sedentary oasis system had intermediate body measurements. This variability between breeds might be due to differences in the growth rate of animals resulting from the adoption of better management practices (feeding conditions) in central hills of Morocco where the agro-pastoral system was practiced than in mountains and eastern upper hills where the pastoral system was adopted. Several researchers (Riva *et al.*, 2004; Agaviezor *et al.*, 2012; Yadav *et al.*, 2013) reported that management system was a source of variation in the body measurements of sheep. The overall coefficients of variation of body measurements were equal to 11.3, 10.6, 12.6, 12.7 and 11.2 percent in Béni Guil, Boujaâd, D'man, Sardi and Timahdite, respectively. For the five breeds, the coefficients were over the mean homogeneity within the breed that corresponds to 10 percent (Arredondo-Ruiz *et al.*, 2013). This reflects differences among the studied animals indicating within-breed variability that might be useful for improving animal size by selection.

The Mahalanobis distances of morphological traits between breeds were highly significant ($P < 0.001$), indicating between breed differentiation. The longest distance was found between Béni Guil and Sardi breeds and the shortest was recorded between Boujaâd and Sardi, Boujaâd and Timahdite, and D'man and Timahdite breeds. The highest distance between Béni Guil and Sardi possibly reflects differences in body size and TL; Béni Guil sheep

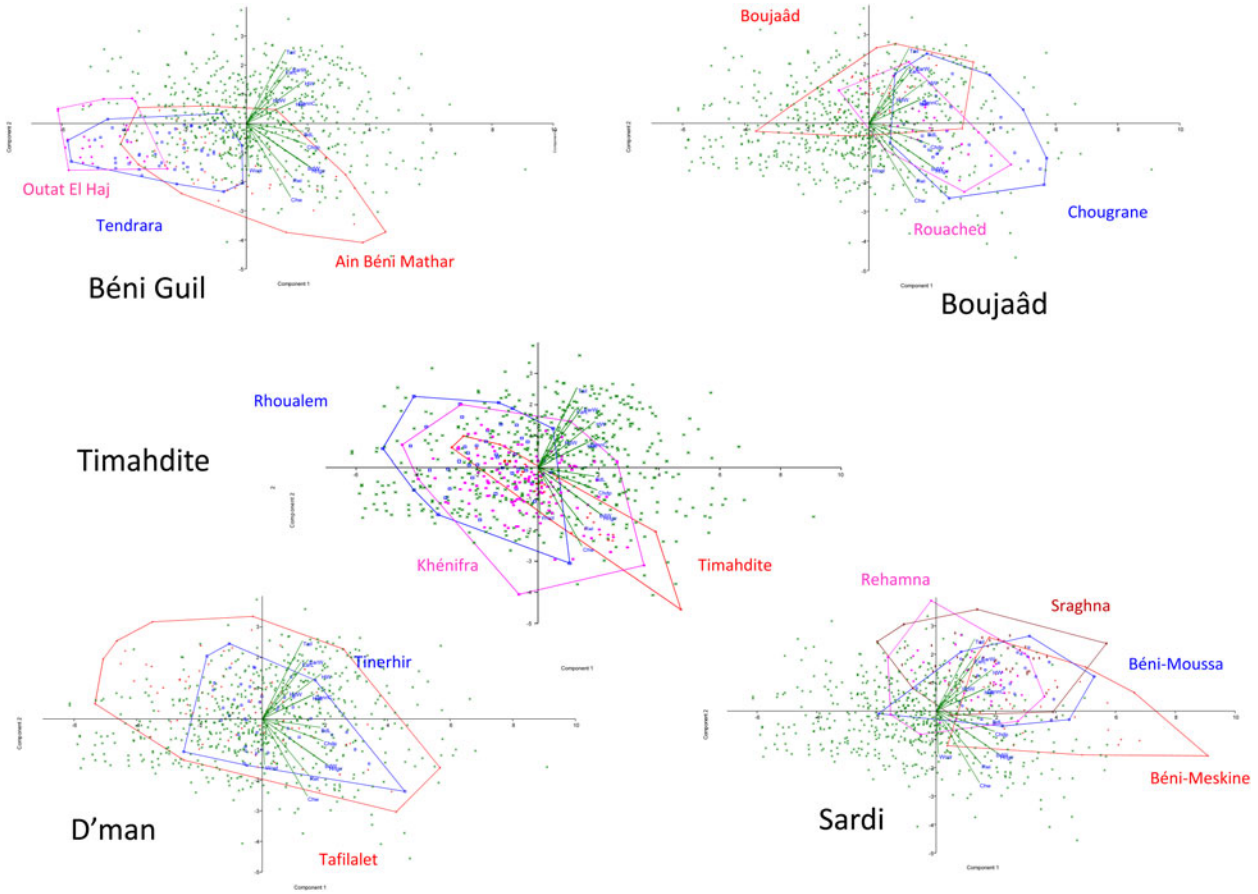

Figure 3. Representation of individuals of each geographic locality-breed on the first two components.

are relatively smaller in size and have a shorter tail compared to Sardi sheep. The shortest distance between Boujaâd and Sardi and between Boujaâd and Timahdite may be due to some gene exchange that had taken place overtime in the past between these breeds because of their geographic proximity that favoured intermixing on pasture during the periods of transhumance. In a study on blood biochemical polymorphism of six Moroccan sheep breeds, using post-albumin, transferrin and haemoglobin Beta systems, Boujenane *et al*. (2008) reported that the phylogenetic tree, constructed from the genetic distances data, divided the breeds into two main branches, with the D'man in one and the remaining breeds in the second branch further branched into two with Béni Ahsen (another local breed) on one branch and the Béni Guil, Boujaâd, Sardi and Timahdite in the other branch. Yunusa, Salako and Oladejo (2013) reported that the genetic distance is important to determine the heterosis expected during crossbreeding; the farther two breeds are, the more the expected improvement when they are crossed.

Discriminant analysis to determine the percentage of individuals correctly grouped 80 and 100 percent of animals into their own breed, confirming the difference between breeds. The low misclassification errors of Béni Guil, D'man and Sardi breeds may be an indication of the uniformity of these breeds suggesting a marked degree of differentiation. Béni Guil sheep were small in body size, so most of them could not be wrongly classified to larger breed, such as Sardi or Boujaâd. It is why no or few Béni Guil animals were erroneously cross-classified as Sardi or Boujaâd sheep. The D'man had a light fleece that differentiated it from the other breeds. Most misclassified Boujaâd individuals were categorized as Sardi animals and vice versa. The breeding areas of these two breeds are close to each other; some genetic exchange might take place between these breeds overtime in the past. Additionally, according to Eyraud (1934), these two breeds have the same origin as they belong to the Western Arabic branch of Moroccan sheep. The varied percentages of misclassified Timahdite animals as Béni Guil and Boujaâd sheep might be explained also by the proximity of their breeding areas; the one of Timahdite is located between those of Béni Guil and Boujaâd, therefore facilitating some gene flow between breeds on pasture at the time of transhumance. Also, it might be due to the origin of Timahdite breed that according to Eyraud (1934) was developed, some centuries ago, from crossbreeding between Boujaâd rams and some Moroccan Atlas Mountain populations, with a low contribution of the Béni Guil breed.

According to the approach (stepwise discriminant analysis, percentage (%) of variance and canonical discriminant analysis), the most discriminating variables between breeds are about the same in decreasing order: TL, WH, HL and WL. This is creditable because the Sardi, Boujaâd and D'man sheep have generally the longest tail hanging below hocks and Béni Guil has the shortest tail hanging above hocks. Also, the Sardi and Boujaâd sheep are generally higher on feet than the other breeds, and the D'man animals have a light fleece with wool of poor quality generally only covering the back. These most morphological discriminant traits should be taken into consideration in establishing studies of racial differences. Furthermore, classification functions obtained in this study could be directly used as criterion for establishing phenotypic standards to identify the Moroccan sheep breeds.

Results from multivariate analyses revealed that morphological variability existed within Moroccan sheep breeds. However, it is worthy to know if the observed variability was due to geographic locality differences (climate, topography, presence of subpopulations, etc.), to sheep management (feeding conditions, health care, etc.) or to other sources. Variance components analysis showed that geographic locality and flock management explained together 38.8 percent of within-breed morphological variability, leaving more than 60 percent variability unexplained. In addition, the variability due to geographic locality had the same overall magnitude as the one caused by flock management (18.1 versus 20.7 percent). However, these contributions varied according to the breed. The high contribution of geographic locality to morphological variability of Béni Guil (26.8 percent) and Sardi (22.4 percent) breeds might be explained by their large breeding areas, which extend over various climatic and topographic zones, whereas its low contribution to D'man variability was because the breed was kept indoors under similar oases environment all year, indicating that differences among D'man animals were mainly due to flock management and other sources, but not to geographic locality. The high contribution of flock management to within morphological variability of D'man, Sardi and Timahdite might be due to the presence in each of their geographic localities of two different categories of breeders; those who joined the ANOC recently, so not having enough training to modern sheep management, and those that were members for a long period, and handling perfectly the management techniques.

The other issue that might be raised concerned the structure of breeds and the future tendency of Moroccan sheep breeds. Since the beginning of 1980s in Morocco, breeding areas of different breeds were delimited by the Ministry of Agriculture. Officially, the same breed should be raised by breeders of each breeding area. Breeders located in a given breeding area who wish to raise a breed different from the one of that breeding area could not take advantage from government training and subsidies. This government's policy had greatly contributed to the homogeneity and preservation of local breeds by avoiding gene exchange between them and exotic gene introduction. However, within a breeding area, the mating system is based on exchange of rams from one breeder to another. Usually, beginner breeders, who just start selection, purchased selected rams from elite flocks located at any geographic locality of the breeding area of that breed in order to improve their sheep flock and to approach the breed standard. These exchanges contributed to the homogenization of breeds. Consequently, there will be in the future a clear tendency towards more differentiation between-breeds and more homogenization within-breeds.

Conclusions

The study revealed a clear variability between the Moroccan sheep breeds indicating a negligible gene flow between them. This was explained by the delimitation of breeding areas set up by the government more than three decades ago. In addition, multivariate analyses showed that morphological differences existed within each breed due to geographic locality and flock management. It was concluded that there is a tendency towards more differentiation between-breeds and more homogenization within-breeds. Also, morphological variations obtained in the current study should be complemented with molecular tools.

Acknowledgements

The first author would like to thank the technicians of ANOC who introduced him to farmers, and all sheep breeders in the study zones for allowing him to use their animals for body measurements. He is also grateful to Miss Halhaly S. and Mr El Makrouz S. for their contribution to the collection of data on some breeds. This study, part of WestMedSheep program, was supported partially by AOI of Limoges University.

Conflict of interest

None.

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Animal Genetic Resources, 2016, 58, 101–110. © Food and Agriculture Organization of the United Nations, 2016
doi:10.1017/S2078633615000417

System characteristics and management practices for small ruminant production in "Climate Smart Villages" of Kenya

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Summary
The CGIAR research programme on Climate Change Agriculture and Food Security, in collaboration with several partners is testing a portfolio of interventions to address the threat of changing climatic conditions for smallholder farming communities living beside river flood plains, grouped into "Climate Smart Villages" (CSVs). We present characteristics of farms in CSV in relation to small ruminant (SR) production and the scenario for a breeding and improvement programme. Information was collated using participatory systems research methods from 140 households in seven CSVs in Nyando basin, Kenya. Although most households were headed by men, there were a higher proportion of adult women within the communities, and literacy levels were moderate. A total of 58 percent of the population owned <1 ha of land for growing crops and rearing on average 6.96 ± 3.35 Tropical Livestock Units comprising different species of animals. Women headed households owned more sheep which were mainly crosses of unspecified local breeds, than Goats which were mainly the Small East African breed-type. Mating among the SR was random, with no control of inbreeding as flocks mixed in grazing fields and at water points. Farmers desired large and resilient animals for better market prices; however, growth rates were slow. The SR flocks were dynamic with 31 percent of the animals moving in and out of flocks in a year. A community breeding programme optimally using available resources and incorporating gender integrated innovative technologies could be implemented for the CSV, alongside strong capacity development on animal husbandry, health and marketing of products.

Keywords: *climate smart villages, management practices, small ruminants*

Résumé
Le programme de recherche du CGIAR sur le Changement Climatique, l'Agriculture et la Sécurité Alimentaire, développé en collaboration avec divers partenaires, a évalué une série d'interventions pour s'attaquer à la menace de conditions climatiques changeantes pesant sur les communautés de petits éleveurs habitant près de plaines alluviales fluviales, groupées sous le nom de "Villages Intelligents face au Climat" (VIC). Nous présentons les caractéristiques des exploitations des VIC par rapport aux performances des petits ruminants et le contexte pour un programme de sélection et d'amélioration. Les informations ont été obtenues en impliquant 140 ménages de 7 VIC du bassin du fleuve Nyando, au Kenya, dans le processus de recherche. Bien que la plupart des ménages étaient dirigés par des hommes, la proportion de femmes adultes dans les communautés a été plus élevée. Les niveaux d'alphabétisation ont été modérés. Le 58 pour cent de la population possédait moins d'un hectare de terre pour les cultures et pour élever, en moyenne, 6.96 ± 3.35 Unités de Bétail Tropical de différentes espèces d'animaux. Dans les ménages dirigés par des femmes, il y avait plus de moutons, résultant essentiellement du croisement de races locales non spécifiques, que de chèvres, celles-ci étant principalement du type racial Petite Chèvre d'Afrique de l'Est. Les accouplements des petits ruminants se faisaient de façon aléatoire, sans aucun contrôle de la consanguinité, puisque les troupeaux se mélangeaient dans les pâturages et aux points d'eau. Les éleveurs souhaitaient avoir des animaux grands et résistants pour pouvoir bénéficier de meilleurs prix sur le marché. Cependant, les vitesses de croissance ont été basses. Les troupeaux de petits ruminants ont été dynamiques, avec un 31 pour cent des animaux entrant et quittant les troupeaux chaque année. Un programme communautaire de sélection employant les ressources disponibles de façon optimale et intégrant le sujet du genre dans les technologies innovantes pourrait être mis en œuvre dans les VIC. Ce programme devrait s'accompagner d'un renforcement des capacités pour le développement de l'élevage, l'amélioration de l'état sanitaire et la commercialisation des produits.

Mots-clés: *petits ruminants, villages intelligents face au climat, pratiques d'élevage*

Resumen
El programa de investigación del CGIAR sobre Cambio Climático, Agricultura y Seguridad Alimentaria, desarrollado en colaboración con varios socios, está evaluando una serie de intervenciones para hacer frente a la amenaza de condiciones climáticas cambiantes sobre comunidades de pequeños ganaderos residentes junto a llanuras aluviales de ríos, agrupadas bajo el nombre de "Aldeas Climáticamente Inteligentes" (ACI). Presentamos las características de las granjas de las ACI en relación a la producción de los pequeños rumiantes y el contexto para un programa de selección y mejora. La información se obtuvo mediante la participación en el proceso de investigación de 140 hogares de 7 ACI en la cuenca del río Nyando, en Kenya. Si bien la mayoría de los hogares eran liderados por hombres, se dio una mayor proporción de mujeres adultas dentro de las comunidades. Los niveles de alfabetización fueron moderados. El 58 por ciento de la

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población poseía menos de una hectárea de tierra para cultivar y para criar, de media, 6.96 ± 3.35 Unidades de Ganado Tropical, entre las cuales se incluían diferentes especies de animales. En los hogares dirigidos por mujeres, predominaban las ovejas, las cuales resultaban principalmente de cruces entre razas locales inespecíficas, frente a las cabras, que eran mayoritariamente del tipo racial Cabra Pequeña de África Oriental. Los apareamientos de los pequeños rumiantes se realizaban de manera aleatoria, sin ningún control de la endogamia, dado que los rebaños se mezclaban en los pastos y en los puntos de agua. Los ganaderos deseaban tener animales grandes y resistentes para poder beneficiarse de mejores precios de mercado. Sin embargo, las velocidades de crecimiento fueron bajas. Los rebaños de pequeños rumiantes eran dinámicos, con un 31 por ciento de los animales entrando y saliendo de los rebaños cada año. Se podría implementar en las ACI un programa de mejora comunitario que emplease de manera óptima los recursos disponibles y que incorporase la cuestión del género en las tecnologías innovadoras. Este programa debería acompañarse de un refuerzo de las capacidades para el desarrollo de la ganadería, la mejora del estado sanitario y la comercialización de los productos.

Palabras clave: *pequeños rumiantes, aldeas climáticamente inteligentes, prácticas de manejo*

Submitted 29 June 2015; accepted 30 October 2015

Introduction

Changing climatic conditions coupled with overexploitation of natural resources have led to great changes in the agricultural potential of land in Kenya. The changing climatic conditions have resulted in changes in precipitation patterns characterized by long periods of dry weather leading to a loss of vegetative cover, followed by periods of very heavy rainfall and subsequent flooding, which threaten and adversely affect communities, notably those that live beside rivers and river floodplains (IPCC, 2007). The Nyando basin in Western Kenya, a rich agricultural flood plain around Lake Victoria is one region that has been adversely affected by the changing climate. The challenges are compounded by the high population density in the area (more than 400 persons/km^2), and a high rate of poverty (Macoloo *et al.*, 2013). Farming is the primary source of income and food in Nyando; however, land holdings are small, and the area suffers serious soil erosion with run-off during rainy seasons that forms deep gullies affecting about 40 percent of the landscape.

From late 2011, the CGIAR research programme on Climate Change Agriculture and Food Security (CCAFS), in collaboration with World Neighbors, Vi Agroforestry and Kenya's Ministry of Agriculture, Livestock and Fisheries have been testing a portfolio of promising climate change adaptation, mitigation and risk management interventions for smallholder farmers grouped into "Climate smart villages" (CSVs). CSVs are the sites where the partners work with farmers using participatory approaches to identify needs, then test the portfolio of agricultural interventions identified for the site, and develop the capacity of the communities to respond to and manage the relevant resources in order to improve their livelihoods. One such intervention has been the introduction of improved strains of indigenous sheep and goats [collectively referred to as small ruminants (SRs)] in a bid to improve the productivity of the local SR.

SRs are important in ensuring food security as they provide households with both nutrition and disposable income. Their small body size, flexible feeding habits and short generation intervals make them suited to the smallholder farming systems. They also require lower initial investment costs, play a complementary role to other livestocks in the utilization of feed resources and are often owned and tended by women and children (Kosgey, Van Arendonk and Baker, 2004; Peacock, 2005). The role of SR in income generation and food security of most smallholder farmers of Kenya is substantial (Peacock, 2005; Ojango *et al.*, 2010), as they enhance the livelihoods of smallholder farmers through the sale of products such as milk, live animals and manure. Outputs from SR within smallholder systems however tend to be low and few initiatives for change are in place. System-based research is thus required to understand the context under which SR are kept, and help the smallholder systems better respond to the changing social, economic and environmental conditions in which they operate (Kosgey and Okeyo, 2007; Rege *et al.*, 2011). In this paper, we outline the characteristics of the SR production environment, and the flock structures and dynamics at the household level within CSV of the CCAFS project in order to determine best-bet options for sustainable SR improvement in the villages.

Materials and methods

Study area

This study was conducted in the Nyando basin, covering two counties of Western Kenya namely, Kisumu County and Kericho County (Figure 1). As part of the CCAFS sites in East Africa, Nyando was selected because it had a range of key bio-physical and agro-ecological gradients; a range of agricultural production systems; an anticipated gradient of temperature and precipitation changes; established research and development partners; long-term socio-economic and weather data; a network of regional partners to facilitate scaling up; and had mitigation and/or carbon sequestration potential (Kristjanson *et al.*, 2012). The main land uses in the area are cultivation of crops and

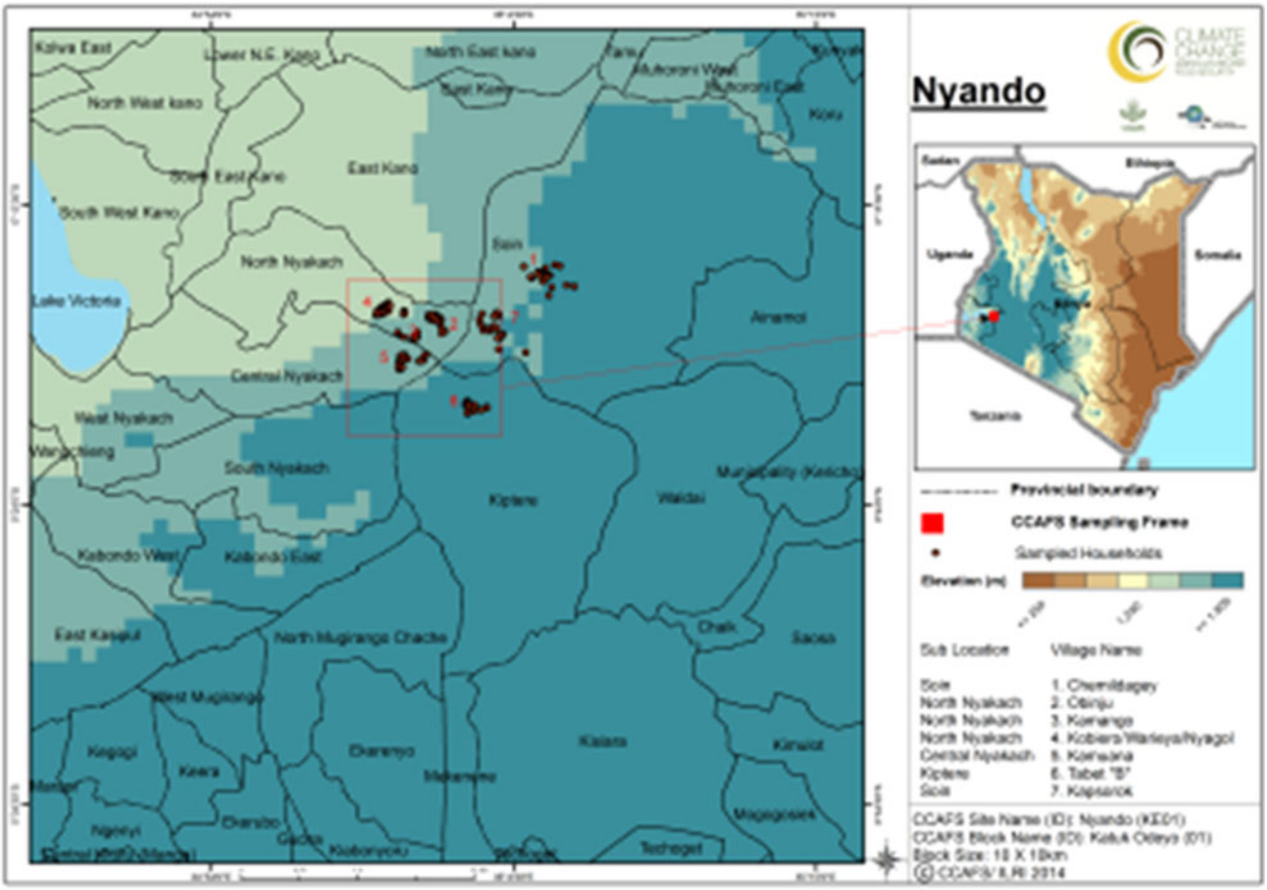

Figure 1. Map of Kenya indicating the Nyando basin and the location of the "Climate Smart Villages".

pasture. Vegetation is scanty in the area, and run-off from seasonal rivers has caused soil erosion, which has resulted in deep gullies that run across large areas and hinder farming activities (Macoloo *et al.*, 2013).

Sampling procedure

In the initial design of the Nyando CSV, 139 households were randomly selected from seven villages which in turn were randomly selected from 106 villages within a 10 × 10 km^2 block of land. The sample size was chosen to enable CCAFS to measure changes in a series of pre-determined indicators over a 5-to-10-year period. Additional details on the sampling frame and regional focus are available at http://www.ccafs.cgiar.org/resources/baseline-surveys.

A requisite sample of households rearing SR was required to provide a base population for genetic improvement within the project area. However, of the 139 households that were part of the initial CCAFS survey on general household characteristics and resource endowment (Mango *et al.*, 2011), only 64 percent owned a minimum of either three sheep or three goats. Households without SR were thus replaced by randomly selecting alternative households keeping SR within the same vicinity. Additional information on the villages and households selected are presented by Ojango *et al.* (2015).

Data collection

A participatory systems research approach was adopted in order to understand the community and the existing management practices and values attached to SR within Nyando. Information was collected at a household level using survey tools developed at the International Livestock Research Institute (ILRI) as part of the CGIAR research programme on livestock and fish (CRP 3.7; http://livestockfish.cgiar.org/). The information collected sought first to establish the characteristics of the various farmers in the CSV and understand their reasons for keeping SR, then to understand the attributes of SR that the farmers consider to be most important, and the dynamics of flocks within the CSV and finally to determine the production constraints, challenges and opportunities for improved productivity of the SR populations in CSV.

The data were collected using the "Open Data Kit" (ODK) information technology platform (https://opendatakit.org/). This enabled direct entry of information provided by each household in an electronic format to a central database, thus saving on time and reducing the number of secondary errors usually associated with manual data collection and entry.

Crosschecking of the information obtained was carried out through a series of focus group discussions during which syntheses of the initial results of the survey were presented and discussed with livestock keepers in the different CSV. Additional interviews and discussions related to the evidence arising from the household survey were conducted with Key informants who included both Public and Private sector actors within the lower Nyando region.

Data analyses

Data analyses procedures comprised both qualitative and quantitative methods. Simple descriptive statistics were used to analyse data across sites. Tests of statistical significance were carried out using either Chi-square (χ^2) or *t*-tests.

Farmers were requested to rank various traits in SR that they perceived to be important in order of preference on a scale of 1–5 (where 1 = most important and 5 = least important). Information generated through this ranking would be useful in developing objectives for improving SR in the CSV. An average score (I_i) for each trait (i) was calculated as follows (adapted from Bett *et al.*, 2008):

$$I_i = \frac{\sum_{j=1}^{5} r_j X_{ji}}{\sum_i \sum_{j=1}^{5} r_j X_{ji}},$$

where X_{ji} is the number of respondents giving rank j, $j = 1, 2, 3, 4, 5$ to trait i, where i = age, sex, size, body condition and breed. r_j is the weight corresponding to rank j. The weight is given by $r = 5, 4, 3, 2, 1$. The weights given for each rank were based of the order of preference, with the highest rank having a higher weight, and the lowest rank having a lower weight.

Results

Farmer characteristics

The general characteristics of the smallholder farmers in the CSV are presented in Table 1. Majority of households from which information was obtained within the two counties were headed by males (Table 1). There were significant differences in the proportion of households headed by women in between the two counties ($P < 0.01$), with Kisumu County having more women-headed households than Kericho County. When looking at the general composition of the households by age group, more than 65 percent of the household members were aged below 25 years in both counties.

Interestingly, within each household, there were a higher proportion of adult women over 15 years of age than adult men (53.43 percent in Kisumu County and 53.09 percent in Kericho County). Literacy levels for the household heads were moderate. Compared to Kisumu, Kericho had a higher proportion of household-heads with a primary school education and therefore could read and write. There were also significant differences ($P < 0.01$) in the level of education of the household heads depending on their genders. Of the men who headed households in Kisumu and Kericho Counties, respectively 56.6 and 65.2 percent had at least a primary level of education,

Table 1. Characteristics of smallholder farmers and their farms in the "Climate Smart Villages".

Variable	Category	Kisumu County	Kericho County
Characteristics of household head			
Gender	Male	60% (53)	74% (46)
	Female	40% (35)	26% (16)
Average age (years, $\mu \pm$ SD)	Male	53.5 ± 16	45.7 ± 14
	Female	56.9 ± 16	51.0 ± 19
Education level	No formal	20.4% (18)	19.35% (12)
	Primary School	54.6% (48)	61.3% (38)
	High School	25% (22)	19.35% (12)
Household size ($\mu \pm$ SE)			
Farm characteristics			
Total land size (hectares)	<0.5	34.7% (51)	17.6% (21)
	0.6–1.0	29.3% (43)	24.4% (29)
	1.1–3.0	29.9% (44)	36.9% (44)
	3.1–6.0	5.4% (8)	10.1% (12)
	>6	0.7% (1)	11.0% (13)
Land tenure[1]	Owned with Title	75% (66)	92% (57)
	Owned but no Title	76% (67)	100% (62)
	Rented/share cropped	11.4% (10)	–
Percent of households owning different species of livestock[2]	Cattle	67% (59)	76% (47)
	Sheep	70% (62)	39% (24)
	Goats	68% (60)	69% (43)
	Poultry	70% (62)	44% (27)
	Donkeys	5% (4)	45% (28)

[1]Households could own different parcels of land under more than one system of tenure.
[2]Households could own more than one species of livestock.

while 34 and 24 percent of them had a high school education. Among the women who headed households, only 51.4 and 50 percent in Kisumu and Kericho counties respectively had at least a primary level education, while much fewer (11.4 percent in Kisumu and 6.2 percent in Kericho) had a high school education. The implications of the gender, age structure and education levels within households on income, asset ownership and livelihoods within the communities requires further investigation as this would potentially have great impact on livestock development within the communities.

Farm characteristics

The parcels of land owned by the farmers were quite small (Table 1). In Kisumu County, 64 percent of the farmers owned <1 ha, while in Kericho County 42 percent of the farmers owned <1 ha. Land available for grazing or growing pastures for animals was limited. Only in Kericho County did a significant percent of farmers (11 percent) own more than 6 ha of land. The farmers tended to keep several species of livestock (Table 1). The number of animals reared per household presented as tropical livestock units (TLU) varied in relation to land size (Table 2). This generally reflects the resource availability for the smallholder farming systems, with less endowed households owning smaller parcels of land and maintaining fewer TLU than better endowed households. Farmers in Kericho County tended to have more cattle and goats than those in Kisumu, while in Kisumu farmers had more sheep than those in Kericho (Table 2). On the very small land holdings (<1 ha), farmers in Kericho County kept more animals than those in Kisumu County.

When gender was taken into consideration 54 percent of the households that kept sheep in Kericho County were headed by women, while in Kisumu County more male headed households owned sheep (63 percent) compared with female headed households. In both counties, a higher proportion of male-headed households owned goats (76 percent in Kericho and 63 percent in Kisumu) than female-headed households. Differences in ownership of SR by gender have great implications on control of incomes that accrue from the sale of the SR and their products.

Access to, and regular availability of water was noted to be a challenge within both counties. Harvesting and storage of rain water was mainly practiced within Kisumu County though only to a small degree, with 4.6 percent of the households harvesting rain water from their roofs, and 23 percent of the households storing rain water in water pans. The main constraints related to availability of water within both counties were; long distances to watering points and seasonality in availability of water. Farmers noted that during the drier periods of the year, the amount of water offered to animals tended to be less than when conditions were wet. In both counties the use of boreholes or wells was minimal.

SR breed-types kept and management practices

A large proportion of the sheep reared (68.5 percent in Kisumu and 60 percent in Kericho) were crosses of unspecified local breed-types. Pure-bred Red Maasai sheep had been introduced in the area for crossbreeding, however the numbers of crosses were still low (9 percent in Kisumu and 17 percent in Kericho). There were also some Dorper and Blackhead Persian sheep in the two Counties; however, their numbers were low.

Unlike what was observed in the case of sheep breeds, a larger proportion of the goats reared in both counties were well-defined breed-wise. The largest proportion of the goat population in Kisumu comprised the Small East African goats (38.7 percent) followed by Galla goats and their crosses (32.3 percent). In Kericho County, there were more Galla goats and their crosses (49 percent) than the Small East African goats (34.2 percent). Other

Table 2. Number of tropical livestock units (TLU) for different species of livestock and mean number of sheep and goats reared by small holder farmers owning different sizes of land the two Counties.

County	Land size (Ha)	TLU for different livestock species (mean ± SD)						Mean number of SR per HH	
		Cattle	Goats	Sheep	Poultry	Donkeys	Overall	Sheep	Goats
Kisumu									
	<0.6	2.0 ± 1.4	0.23 ± 0.25	0.44 ± 0.27	0.10 ± 0.04	–	2.7 ± 0.2	5.8 ± 4.9	1.3 ± 0.3
	0.6–1.0	3.2 ± 2.1	0.43 ± 0.38	0.60 ± 0.50	0.10 ± 0.08	–	4.3 ± 0.1	5.6 ± 4.4	5.3 ± 3.8
	1.1–3.0	4.0 ± 2.4	0.48 ± 0.28	0.44 ± 0.26	0.11 ± 0.09	2.0 ± 0.6	7.0 ± 0.1	5.0 ± 2.8	5.0 ± 2.5
	3.1–6.0	4.8 ± 2.7	0.53 ± 0.30	0.81 ± 0.71	0.11 ± 0.08	2.0 ± 0.6	8.3 ± 0.2	8.6 ± 8.5	4.6 ± 2.7
	>6.0	9.0 ± 4.9	0.40 ± 0.14	1.93 ± 1.81	0.10 ± 0.05		11.4 ± 1.3	11.0 ± 0	4.0 ± 0
Kericho									
	<0.6	3.3 ± 2.56	0.70 ± 0.26	–	0.1 ± 0.04	0.8 ± 0	4.9 ± 0.4	–	8.0 ± 2.8
	0.6–1.0	5.0 ± 1.78	0.65 ± 0.37	–	0.06 ± 0.03	2.4 ± 0	8.1 ± 0.7	–	4.8 ± 3.8
	1.1–3.0	4.9 ± 4.00	0.68 ± 0.52	0.23 ± 0.14	0.05 ± 0.05	0.87 ± 0.24	6.7 ± 0.1	2.6 ± 1.3	6.9 ± 5.3
	3.1–6.0	5.3 ± 2.79	0.65 ± 0.46	0.44 ± 0.33	0.07 ± 0.06	0.89 ± 0.26	7.4 ± 0.1	4.7 ± 3.1	6.6 ± 5.3
	>6.0	7.2 ± 4.91	0.91 ± 0.71	0.50 ± 0.54	0.06 ± 0.03	1.2 ± 0.67	9.9 ± 0.2	4.9 ± 5.4	9.1 ± 6.9

TLU of 250 kg live weight (Njuki *et al.*, 2011).

goat breeds found in the areas were the Alpine and crosses between the different breed-types.

The breed-types of sheep and goats owned differed depending on the gender of the household head, with a higher proportion of the female headed households owning pure Red-Maasai sheep and their crosses (Red Maasai × Dorper in Kisumu and Red Maasai × Blackhead Persian in Kericho). Also in both Counties, the male headed households had more of the Galla goats and their crosses than the female headed households. When mating animals, the farmers practiced both pure breeding and crossbreeding of their sheep and goat populations. They noted that cross-bred animals had better (i.e. more desirable) attributes for their environments than either the pure-bred local animals, or the introduced pure-breeds.

SR flocks for all the farmers had a higher proportion of mature female animals (>50 percent) than other age groups (Figure 2). The flocks however also comprised 20 percent mature male animals. Very limited control of breeding was practiced across the villages.

Rams used for mating in Kisumu County were said to be mainly home-bred (41 percent of the households), while in Kericho County, farmers noted that they bought rams from other farmers or through development projects. More than 25 percent of the households in the two Counties however indicated that they used rams in an opportunistic manner as they left their sheep in open pastures and any ram from within the vicinity mated their ewes.

For goats, a significantly high proportion (65 percent in Kisumu and 57 percent in Kericho, $P < 0.05$) of the bucks used for breeding was sourced from outside the farms either from other farmers, or through activities of development projects within the areas. Twenty two percent of the farmers in both counties however noted that they bred their own bucks, while the rest relied on random mating during grazing and at shared water points. None of the farmers indicated that they had specific measures in place to control inbreeding among the SR reared.

SRs kept were mainly fed stovers of planted maize, millet and sorghum after harvesting of the crops, implying seasonal variation in SR feed resources. In a few instances,

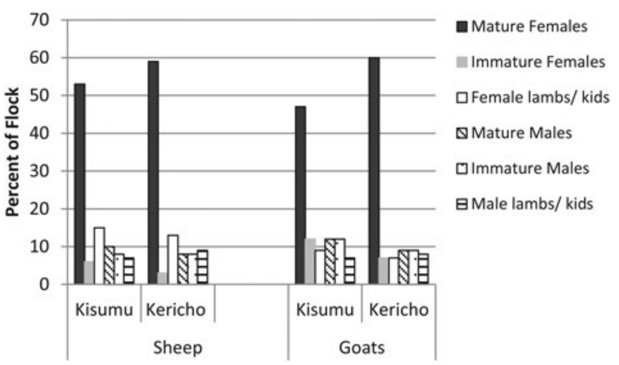

Figure 2. Flock structure for sheep and goats in the small holder farming systems.

the farmers purchased dry crop residues from neighbouring farms to feed their SR. Stover was generally obtained from the fields directly by the animals, however, 58 percent of the households in Kisumu and 65 percent of the households in Kericho County indicated that they sometimes chopped the stovers into smaller pieces using a hand held blade prior to feeding it to their SR. Concentrates and/or mineral supplements were provided by some of the farmers (37 percent versus 25 percent in Kericho and Kisumu County, respectively), while 26 percent of the farmers in Kisumu and 55 percent in Kericho purchased processed feeds for their SR.

SR trait preferences

The traits perceived as being of primary importance in SR and their ranking in order of importance based on an index calculated from the scores provided on each trait by the farmers are presented in Table 3.

The size and body condition of the animal were the most important traits for the farmers. This tended to be linked to the possible price the animals could attract in the market and, irrespective of breed type, larger animals were sold for better prices than smaller animals.

Flock dynamics

The flock numbers and structure within the farms was dynamic. Over a 12-month period, it was noted that 29 percent of the sheep and 34 percent of the goats had left the flocks in Kisumu County, while 27 percent of the sheep and 18 percent of the goats had left the flocks in Kericho County. Though animals exiting flocks were said to have been sold through different channels (Figure 3), the farmers noted that the mortality rates in the flocks, particularly for sheep were high (15 percent in Kisumu and 19 percent in Kericho). The mortality rates were significantly different ($P < 0.01$) between sheep and goats within the two counties, with a higher proportion of the sheep that left the flocks noted to have died (53 percent in Kisumu and 70 percent in Kericho) relative to goats (32 percent in Kisumu and 19 percent in Kericho).

Table 3. Relative ranks for traits perceived by farmers as being of primary importance in both sheep and goats.

Trait	Kisumu County			Kericho County		
	Total score	Index	Rank	Total score	Index	Rank
Age	216	0.16	4	116	0.12	5
Sex	251	0.18	3	140	0.15	4
Size/conformation	373	0.27	1	240	0.25	2
Body condition/ nutritional status	318	0.23	2	270	0.28	1
Breed	218	0.16	4	184	0.19	3

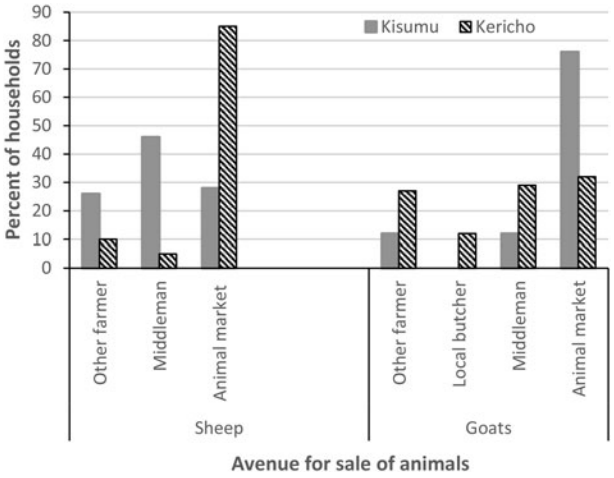

Figure 3. Percent of households selling sheep and goats through different avenues.

There were also a significant number of new entries into the flocks through births and purchases, therefore the total population of SR remained relatively stable. In Kisumu County, 24 percent of all the sheep and 32 percent of all the goats comprised new animals while in Kericho County, 33 percent of all the sheep and 31 percent of all the goats comprised new animals. More than 60 percent of the new animals in both counties were born within flocks and were thus of local indigenous breed-types and their crosses with introduced breeds which the farmers owned. New animals were bought either to replace animals that had been lost, or as reserves for sales at later dates. Animals purchased tended to be mature, with farmers giving preference to body condition than to age. The selection of the animals to be purchased can have a great influence on the possible improvement of flocks, especially because older animals available for sale in markets could have been culled for various reasons by the original owner.

Animal health services were generally available through trained private animal health assistants. The farmers were also quite knowledgeable of the main diseases that affected their SR as presented in Table 4. Not all animals had been vaccinated against diseases with <50 percent of the farmers indicting that they had vaccinated their animals against some of the diseases listed in Table 4.

Discussion

Previous studies have noted that breeding programmes must be preceded by full characterization of the available genetic resources (Jaitner *et al.*, 2001; Kosgey and Okeyo, 2007; Bett *et al.*, 2009).The context under which SR are kept, and the reasons for keeping them needs to be understood before initiating any genetic improvement programme. This study was undertaken in order to provide an insight to the importance of SR under smallholder farming conditions where livestock keepers have very limited resources and are faced with the challenge of changing climatic conditions.

Table 4. Main diseases noted to affect SRs in the two Counties.

Disease	Species affected	
	Sheep	Goats
Contagious Caprine Pleural Pneumonia	✓	✓
Sheep pox	✓	✓
Rift Valley Fever	✓	–
Blue tongue	✓	–
Lumpy skin	✓	✓
Diarrhoea	✓	✓

Household structure and gender

Households in the communities studied were generally headed by older persons (>50 years). A substantial proportion of those heading households had either no formal education, or only a basic primary level of education. Farming practices implemented were mainly those learned from within the communities. In a study on breeding practices in dairy goat populations, Bett *et al*. (2008) noted that having a high proportion of farmers being elderly may have a negative impact on breed improvement efforts. Within the households of Nyando, there was however a sizable proportion of young people within the population who could be influenced to improve SR productivity.

A strong association between SR production and gender was observed in the CSV of Nyando. Specifically, goats tended to be owned by men, while sheep were owned by the women. Not surprisingly, more of the women headed households had adopted the improved Red-Maasai sheep breeds that were introduced, while more male headed households adopted the improved Galla goats. This pattern in ownership was different to that reported for West Africa where women tend to own and have greater control of goats and their products, while the men own a greater proportion of the sheep (Jaitner *et al.*, 2001; Ejlertsen, Poole and Marshall, 2013). Ownership of livestock by either men or women in communities is greatly influenced by culture with small stock in many communities left under the responsibility of women and children (Ahuya, Okeyo and Peacock, 2005; Bett *et al.*, 2008; Peacock *et al.*, 2011). When asked on the pricing of SR in the CSV through focus group discussions, it was clear that in Nyando goats fetch higher prices than sheep.

Resource endowment

The limited land that is available to the households in the CSV greatly impacts flock sizes and structure and has implications for sustainable flock/herd productivity. Water availability was also limited, with great variations depending on the season. As the farming practices were geared towards subsistence production, fodders for SR were limiting. The Nyando area has a very short growing period for crops, when farmers tend to use all the available arable land to grow subsistence crops (Macoloo *et al.*, 2013). During such periods there is little land available for both grazing and fodder production. Feeding of SR tended to depend heavily on crop residues. Studies have shown that under-feeding and poor quality feed are some of the major factors that limit SR production (Gatenby, 1986). In the CSV of Nyando, the farmers noted that it takes long (an average of 4 years) for a sheep or goat to grow and reach a mature size, worse still the mature sizes are still quite small in comparison with indigenous sheep and goats from other parts of Kenya. Slow growth rates lead to low offtake rates, which in turn limit flock/herd productivity and incomes from SR. Farmers therefore need to adopt practices that promote fodder production as an economic activity to boost livestock productivity within the area. Manure from the SR could also be used to improve soil fertility, which in turn would improve crop productivity and quantity of fodder available for animals.

Trait preferences and flock dynamics

The farmers in the CSV considered size and body condition as the most important traits in their SR. They were however concerned about the slow growth rates, and differential mortality across the sheep and goats. For SR improvement in the CSV, the breeding objective traits should correspond to what the livestock keepers consider important. However, the production levels targeted should be supported by husbandry practices, practical feasibility and the market for SR (Kosgey and Okeyo, 2007).

Generally growth related traits are highly heritable, easy to measure and are therefore relatively easy to improve through selection or crossbreeding. However, as the feed and water resource base needs to be taken into consideration, a trade-off is needed between improving production (meat and milk traits) and improving the more functional traits (adaptability, survival and reproductive efficiency). With the very small flock sizes at individual farm level, the loss of even one animal is indeed very costly to a household. High mortality together with the long-time taken for a female animal to grow to a weight where it can breed negates potential productivity and offtake of any livestock enterprise.

Demand for SR products was high within the area and larger animals were more easily marketed than the smaller ones. The sale of SR provided buffer income for periods when crop products were not available for sale. The market chains for SR production in the lower Nyando area are however still undeveloped. The markets do not segregate very much based on the quality of the animals. The farmers also lacked expertise and animal husbandry skills to develop a specific quality of SR product for the market, which may strongly influence the value of an animal in traditional markets as noted in smallholder farming systems of Ethiopia by Gizaw, Komen and van Arendonk (2010). A strong training package including animal husbandry, management and marketing of products that targets both the youth and more mature livestock keepers would need to be implemented.

Breeding and improvement programme

Bett *et al.* (2009) indicated that improving SR productivity in unfavourable environmental conditions can generally be enhanced by focusing on improving husbandry. However, in low-input systems where farmers tend to avoid risks and dependencies, introduction of genes from other “exotic” populations at the initial stages of a breeding and improvement programme can be successful and is recommended as long as the functions and attributes of existing populations are duly taken into account (Peacock *et al.*, 2011; Mueller *et al.*, 2015). Indigenous tropical breeds of sheep and goats that have adaptive and productive attributes could serve as good candidates for such introductions (Baker and Gray, 2004). However, such animals need to be carefully selected so that they meet the needs and aspirations of the farming communities to which they are being introduced and should have the potential to adapt to the new environments. In many instances, improved indigenous lines are not available, resulting in the introduction of exotic breed lines unable to cope with the long-term stresses of tropical environments. This has often negatively impacted livestock improvement programmes in developing countries as high resultant mortalities of exotic breeds render livestock keepers destitute (Kosgey *et al.*, 2006). The changing climatic conditions have catalysed the need for developing countries to invest in selecting and developing productive yet resilient indigenous breed lines able to cope with the changes, while at the same time improving the livelihoods of their keepers.

The need for improving household incomes demands that any new livestock improvements or interventions should be market orientated. The mode of implementation of a breeding programme needs to be adapted with cognisance of the prevailing literacy level of the communities targeted. Simple animal identification and monitoring practices should be used to generate data and information on both the animals and the production systems. Results generated through analysis of the data collected should be illustratively presented in order to guide flock management and breeding decisions. In smallholder systems operated by households with diverse age groups and differential levels of literacy working collectively, all the households within the community can undertake the performance and pedigree recording of their animals. This would enable male animals to be selected at reasonably younger ages (9–12 months of age). The selected males can then be retained by a few farmers and used for breeding by the community members (Peacock *et al.*, 2011; Mueller *et al.*, 2015). In order to avoid the risk of “improved” female animals being exposed to non-improved males within the population, some form of control can be implemented through early castration of male progeny from the general population. As the average flock sizes are small, gains would be possible through a group approach to breeding (Gizaw, Hans and van Arendonk, 2009; Mueller *et al.*, 2015). The gain in growth and mature size of animals within the population should however be optimized in line with feed resources and environmental conditions. The CSV provide a good platform for developing an optimized community breeding programme for SRs. Formation of farmer groups, provision of breeding stock, extension and animal health services and training could serve as an incentive for farmers' to participate in the programme as described by Bett *et al.* (2009).

For improved SR to sustainably contribute to transformation of livelihoods and household incomes, a fully integrated approach that is grounded on principles of genetic and better economic management of livestock resources is required. Improving productivity per animal is the most efficient way of mitigating ecological degradation, high water consumption and excessive emissions of green-house gases as reported in "Livestock's Long Shadow – Environmental Issues and Options" (Steinfeld *et al.*, 2006).

Conclusions

In situations and production systems such as the ones found and practiced in Nyando, SRs can play an important role in both adapting to climate change and mitigating the effects of climate change on livelihoods of affected communities. A community breeding programme geared towards the optimal use of available resources and incorporating gender-integrated innovative technologies can be developed using indigenous breeds. Economic breeding objectives however need to be developed for the area. Complementary to this the SR product market value chain should grow. Capacity development is however required to improve husbandry and to sensitize farmers on cooperation in decision making on the improvement and progress of their flocks.

Acknowledgements

The support and contribution of colleagues in the CCAFS Nyando project from ViAgroforestry and World Neighbors is acknowledged. We also acknowledge the livestock keepers within Kisumu and Kericho Counties for their time and support for the project. We would also like to thank the Government of Kenya officers for their assistance towards logistics and to the enumerators who spent many days collecting data.

Statement of interest

No conflict of interest.

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Animal Genetic Resources, 2016, 58, 111. © Food and Agriculture Organization of the United Nations, 2016
doi:10.1017/S2078633616000151

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Advances in farm animal genomic resources

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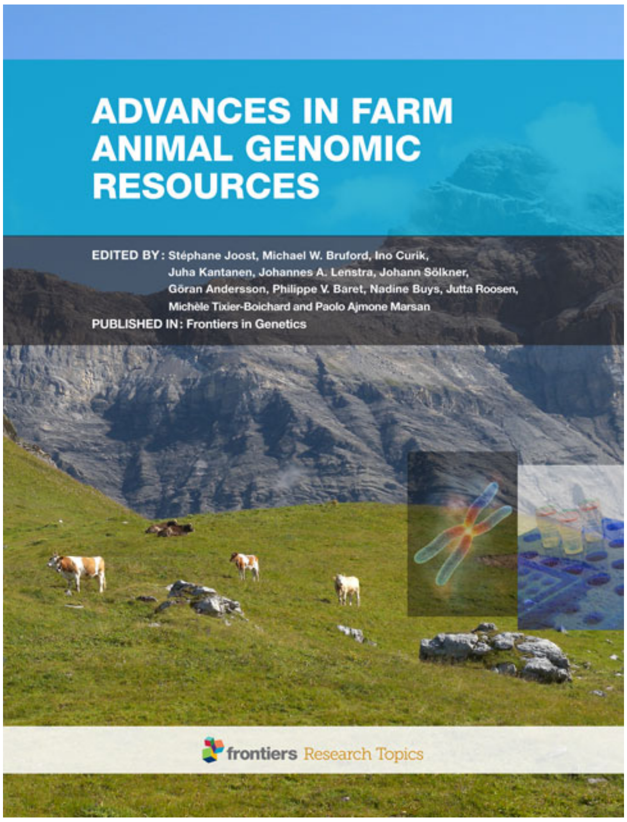
Frontiers in Genetics Published in 2016, pp. 293
ISBN 978-2-88919-735-4
Available at http://journal.frontiersin.org/researchtopic/2123/advances-in-farm-animal-genomic-resources

doi:10.1017/S2078633616000151



The history of livestock started with the domestication of their wild ancestors: a restricted number of species allowed to be tamed and entered a symbiotic relationship with humans. In exchange for food, shelter and protection, they provided us with meat, eggs, hides, wool and draught power, thus contributing considerably to our economic and cultural development. Depending on the species, domestication took place in different areas and periods. After domestication, livestock spread over all inhabited regions of the earth, accompanying human migrations and becoming also trade objects. This required an adaptation to different climates and varying styles of husbandry and resulted in an enormous phenotypic diversity.

Approximately 200 years ago, the situation started to change with the rise of the concept of breed. Animals were selected for the same visible characteristics, and crossing with different phenotypes was reduced. This resulted in the formation of different breeds, mostly genetically isolated from other populations. A few decades ago, selection pressure was increased again with intensive production focusing on a limited range of types and a subsequent loss of genetic diversity. For short-term economic reasons, farmers have abandoned traditional breeds. As a consequence, during the 20th century, at least 28% of farm animal breeds became extinct, rare or endangered. The situation is alarming in developing countries, where native breeds adapted to local environments and diseases are being replaced by industrial breeds. In the most marginal areas, farm animals are considered to be essential for viable land use and, in the developing world, a major pathway out of poverty.

Historic documentation from the period before the breed formation is scarce. Thus, reconstruction of the history of livestock populations depends on archaeological, archeozoological and DNA analysis of extant populations. Scientific research into genetic diversity takes advantage of the rapid advances in molecular genetics. Studies of mitochondrial DNA, microsatellite DNA profiling and Y-chromosomes have revealed details on the process of domestication, on the diversity retained by breeds and on relationships between breeds. However, we only see a small part of the genetic information and the advent of new technologies is most timely in order to answer many essential questions.

High-throughput single-nucleotide polymorphism genotyping is about to be available for all major farm animal species. The recent development of sequencing techniques calls for new methods of data management and analysis and for new ideas for the extraction of information. To make sense of this information in practical conditions, integration of geo-environmental and socio-economic data are key elements. The study and management of farm animal genomic resources (FAnGR) is indeed a major multidisciplinary issue.

The goal of the present Research Topic is to collect contributions of high scientific quality relevant to biodiversity management, and applying new methods to either new genomic and bioinformatics approaches for characterization of FAnGR, to the development of FAnGR conservation methods applied ex-situ and in-situ, to socio-economic aspects of FAnGR conservation, to transfer of lessons between wildlife and livestock biodiversity conservation, and to the contribution of FAnGR to a transition in agriculture (FAnGR and agro-ecology).

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I5915Tri/1/07.16