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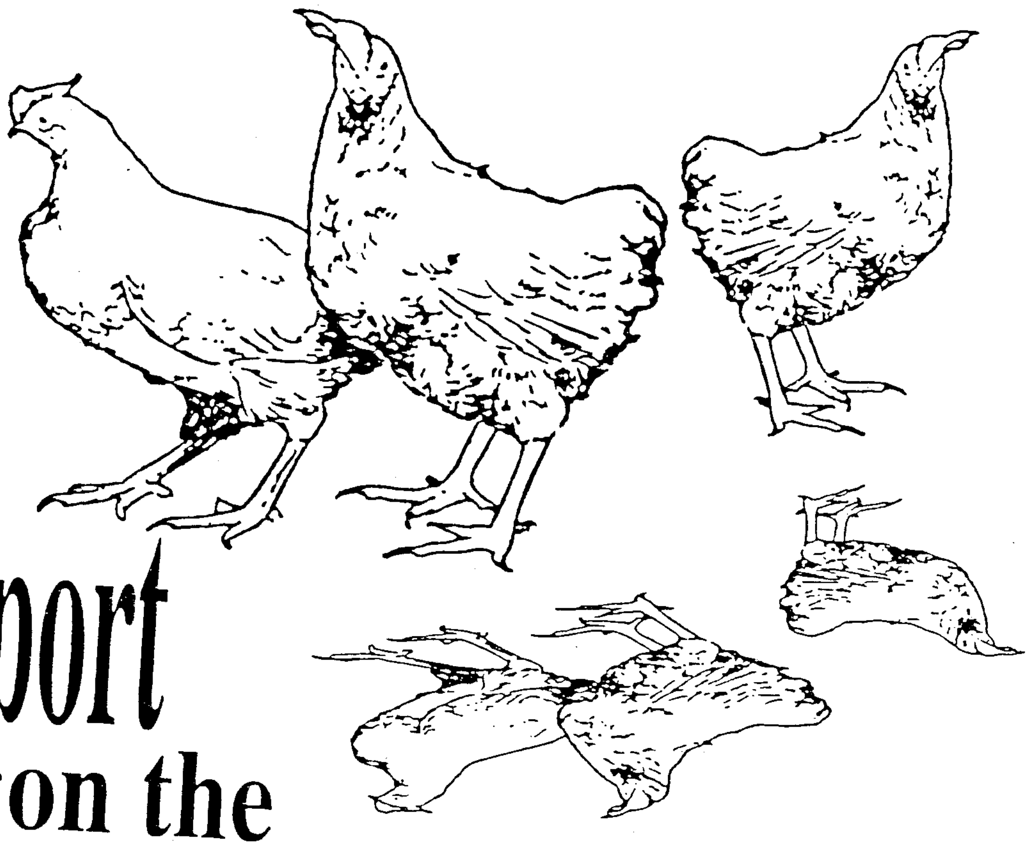

Report on the Welfare of Laying hens

DIRECTORATE-GENERAL FOR AGRICULTURE
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Directorate-general for Agriculture
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Report of the Scientific Veterinary Committee, Animal Welfare Section on the Welfare of laying Hens

<u>(Brussels, 30 October 1996)</u>

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PREFACE

Council Directive 88/166/EEC (E.C. 1988) lays down minimum standards for the protection of laying hens kept in battery cages. Article 9 of that Directive states:

> "Before 1 January 1993 the Commission shall submit a report on scientific developments regarding the welfare of hens under various systems of rearing and on the provisions in the Annex accompanied by any appropriate adjustment proposals".

In May 1992 the Scientific Veterinary Committee (Animal Welfare Section) adopted a report (prepared by a working group under the chairmanship of Prof. Dr. W. de Wit) setting out the latest available scientific information on the welfare of hens. The Commission took no further action on the matter at that time.

Mr. F. Fischler, Commissioner for Agriculture, decided to present a report to the Council by Autumn 1996. The Commission services therefore requested the Scientific Veterinary Committee (Animal Welfare Section) to review and update the report of 1992.

The Committee established an expert working group under the chairmanship of Dr. H.J. Blokhuis. The members of this group listed below were invited on the basis of their scientific expertise in the field and not as representatives of their country.

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The report which follows gathers together and presents the current scientific evidence regarding the welfare of laying hens in various housing systems. It was produced by this expert group and approved by the Scientific Veterinary Committee.

CHAPTER 1

WELFARE: DEFINITIONS AND MEASUREMENT

1.1 Introduction

Concern about farm animal welfare appears to be based on the assumption that animals can experience pain, distress and probably pleasure, and that people have moral obligations to the animals with which they interact. This has led to animal welfare being on the political agenda of several European countries.

Legislation varies, but most countries have ratified the Council of Europe's Convention on the Protection of Animals kept for Farming Purposes. Article 3 of that Convention states that "Animals shall be housed and provided with food, water and care in a manner which, having regard to their species and their degree of development, adaptation and domestication, is appropriate to their physiological and ethological needs in accordance with established experience and scientific knowledge" (Council of Europe, 1976). Under this Convention there is a recommendation on laying hens (Council of Europe, 1995).

In addition to political debate, academic debate about animal welfare has increased. Scientists have added to knowledge of the physiological and behavioural responses of animals and philosophers have developed ethical views on animal welfare. Opinions differ, however, in how science and philosophy should be combined to enable decisions to be taken about the welfare of animals in intensive housing systems. Some authors propose that science and philosophy should be kept separate. For example, it is argued that scientific results must be obtained and interpreted objectively before ethical judgements and subjective interpretation are made (Broom, 1996; Mason and Mendl, 1993). Many scientists stop short of taking this step to subjective interpretation of their experiments. Other authors have outlined a series of steps from science to philosophy, describing the important considerations and assumptions at each step (Sandoe and Simonsen, 1992). Yet others argue that science itself cannot be value-free because scientists are people with views and opinions that influence how they approach their research and the techniques they choose to use (Rollin, 1996; Tannenbaum, 1991). Nevertheless, all agree that decisions about animal welfare should be based on good scientific evidence (c.f. Broom, 1988, Duncan, 1981).

This report gathers together the scientific evidence regarding the welfare of hens in various housing systems. This Chapter includes a brief description of the biological character of domestic fowl. This is followed by a section on the different definitions of animal welfare. There is then a section on assessing animal welfare, where the background to the four main indicators of animal welfare (health, production, physiology and ethology) are presented, followed by a summary of each of the indicators. In the final section, the importance of combining results from several indicators and the relative merits of design and production criteria to assess animal housing are discussed.

1.2 Biological Characteristics of Domestic Fowl

The ancestor of the domestic fowl is the Red Jungle Fowl (Gallus gallus). Modern forms of these jungle fowl are still found today in S.E. Asia and the domesticated bird can be regarded as a subspecies (G. gallus domesticus). Estimates vary but domestication is thought to have occurred about 8000 years ago, first in India and China, then spreading along trade routes. Initially birds were probably used for sacrifice in religious ceremonies or for cockfighting. It was not until the Roman times that the bird's potential as an agricultural animal was developed and laying strains, and even a poultry industry, were established (Wood-Gush, 1959). This industry collapsed when the Roman Empire collapsed and large scale selection of birds for commercial use did not resume again until the nineteenth century. A more complete history of the domestic chicken is presented by Wood-Gush (1959) and Yamada (1988).

Several characteristics predisposed jungle fowl to domestication. They are social, living in groups of 1-2 males and 2-5 females plus young, which has allowed them to be managed in groups. They have a hierarchical structure, probably based on individual recognition, which reduces the risk of injury caused by fighting. They show promiscuous sexual behaviour, which allows any male to be mated with any female and so facilitates artificial selection. Fowl have flexible dietary requirements and are adaptable to a wide range of environments. All these traits have been used to advantage in commercial poultry production (Appleby *et al.*, 1992). Considering the close proximity of humans during management procedures, the all female group composition and the intensive housing used by the egg laying industry, the species has adapted well. Welfare can be threatened, however, if conditions are beyond the birds' adaptive capabilities.

Whereas the jungle fowl hen can lay up to 60 eggs per year a modern commercial laying hen usually lays over 300 eggs during the same time period. Besides increasing laying rate, artificial selection has also increased the mean weight of the egg and the food conversion efficiency of the birds, along with other production traits to maximise efficiency. However, with the exception of selection against brooding behaviour, there have been remarkably few changes in the behavioural repertoire. Those changes that are apparent when comparing modern birds with older strains or feral populations seem to be in threshold of response rather than a change in behaviour per se (McBride *et al.*, 1969; Wood-Gush *et al.*, 1978).

Jungle fowl and domestic fowl are prey species and as such are well designed to detect and avoid predators. Vision is important. They have a well developed colour vision and a visual field of about 330 degrees. Hearing is also important. They are sensitive to frequencies in the range of 15 to 10,000 Hz and have a repertoire of about 20 separate calls (Wood-Gush, 1971) including distinguishable calls for ground and aerial predators. Sight and sound are used for communication and social recognition. Sexual and aggressive displays are highly developed (Kruijt, 1964, Wood-Gush, 1971).

Jungle fowl are omnivores, spending a large portion of their day pecking and scratching in the ground for seeds, worms and insects (Collias and Collias, 1967). Studies in free ranging jungle fowl in zoos have estimate that birds spend up to 61% of their time ground pecking (Dawkins, 1989). Domestic hens also spend a large proportion of their day pecking and scratching (Hansen, 1994). The beak is the main exploratory organ for the bird. It is well innervated with a collections of touch receptors at the end which allows birds to peck accurately (Gentle and Breward, 1981; 1986).

It is beyond the scope of this report to review the cognitive abilities of birds or to comment on the emotions or feelings of laying hens. However, birds possess pain receptors and show aversion to certain stimuli, which can be interpreted as that they experience pain (Gentle *et al.*, 1990). They show fearful behaviour and avoid frightening situations, implying that they experience fear (Jones and Faure, 1982; Jones, 1986). They show behaviour indicative of frustration (Duncan, 1970). If suffering is defined as "a wide range of unpleasant emotional states" (Dawkins, 1980) then it is clear that domestic fowl are capable of suffering.

1.3 Definitions of welfare

Although there are some differences of opinion concerning the use of the terms "welfare" and "well-being" (c.f. Fraser, 1989; Hughes, 1989), both terms are used when referring to the state of animals. In this report the term "welfare" and not "well-being" will be used.

In discussions about animal welfare several definitions and descriptive statements have been used. Some of the more commonly quoted include:

1. Brambell report (1965): "Welfare is a wide term that embraces both the physical and mental well-being of the animal. Any attempt to evaluate welfare, therefore, must take into account the scientific evidence available concerning the feelings of animals that can be derived from their structure and function and also from their behaviour".

2. Lorz (1973): "Living in harmony with the environment and with itself, both physically and psychologically".

3. Hughes (1976): "Welfare is a state of complete mental and physical health, where the animal is in harmony with its environment".

4. Wiepkema (1982): "The inadequacy of the programmes performed to control relevant aspects of the Umwelt, or the permanent failure of any behaviour, must cause severe feelings of distress. In this period the animal really suffers and its well-being is at stake".

5. Broom (1986): "The welfare of an individual is its state as regards its attempts to cope with its environment".

6. American Veterinary Medical Association (1987): "Distress is a state in which the animal is unable to adapt to an altered environment or to altered internal stimuli. If such stressors are short term, responses an animal will make to adapt to these changes do not usually, but may, result in long-term harmful effects. Prolonged or excessive distress may result in harmful responses, e.g., abnormal feeding and social interaction behaviour, inefficient reproduction, and can result in pathologic conditions, e.g., gastric and intestinal lesions, hypertension, immuno suppression. Distress also may be induced through changes in internal states such as disease, nausea, excessive anxiety, and fear. Such responses may become a permanent part of the animal's repertoire and seriously threaten the animal's well-being".

7. "Animal welfare is dependent solely on the cognitive needs of the animals concerned" (Duncan and Petherick, 1989).

8. "Let us not mince words: Animal Welfare involves the subjective feelings of animals" (Dawkins, 1990).

Some of these statements are rather descriptive (1 and 6). Others refer the an animal being in harmony with its environment (2 and 3) and, although commonly quoted, are not very helpful in scientifically assessing the welfare of animals under different conditions. Others refer to adaptation to or control of the environment by the animal (4 and 5) and seem more operational. Some are specifically concerned with the subjective experiences of the animal (7 and 8).

Although there is no single definition for animal welfare, scientists do agree on the overall meaning of the term. That is to say, the more effort the animal is putting into coping, or the greater the biological cost of responding, the worse the animal feels and the poorer it's welfare (Broom, 1996; Duncan, 1996; Moberg, 1996). The differences lie only in where the emphasis should be placed. There are many common terms which elude definition e.g. quality and safety, and this does not prevent them being useful. In most cases, the term welfare is used to cover a continuum from very poor to very good welfare.

1.4 Assessment of Welfare

Before describing the health, production, physiological and ethological indicators of animal welfare, it is necessary to give a general picture of why these indicators have been selected by researchers. This is best achieved by outlining where they fit into the complex of interactions between the animal and it's environment.

In the course of evolution every animal species is adapted to an environment in which it is able to regulate its internal state and to survive and reproduce. Regulatory systems in animals consist of responses to changes in that environment which allow the animal to keep internal and external conditions at an optimal level. In other words, the animal tries to control its environment by using various coping mechanisms.

Wiepkema (1985) proposed a regulatory model of welfare in which environmental factors (internal and external) are compared with a set point. He introduced the concept that higher animals may not only react to environmental changes, but may also predict and anticipate these changes. It appears that reduced predictability or controllability of relevant environmental changes are important causes of typical behavioural and physiological stress symptoms. Welfare cannot, therefore, be equated with homeostasis (Collier and Johnson, 1990). Nor is there necessarily a consistent pattern of responses across all individuals in a given situation.

To allow an animal to make an appropriate response in a specific situation, it is important that it continually monitors the effectiveness of its regulatory actions. Wiepkema (1985) suggests that emotions or feelings are involved in this monitoring. Positive feelings are experienced when regulatory action is effective (coping responses are successful) and negative feelings are experienced when this is not the case. Broom (1996) also argues that feelings are part of a mechanism that has evolved in higher animals to help them achieve an end result more effectively. Duncan (1996) takes this point further by arguing that welfare of sentient animals is all about feelings. He agrees that there will usually be a good correspondence between the physiological states and the emotional states, for example being stressed and feeling stressed, but also points out occasions when the higher level emotions do not mirror the lower level reactions. For this reason he proposes that it is the feelings that should be measured.

A simple and energetically low cost response of an animal may be a behavioural response e.g. to move to a warmer location. Several techniques are available to study these behavioural responses (ethological indicators). Animals are also responding physiologically to environmental changes e.g. changes in heart rate, and techniques are available to study these physiological responses (physiological indicators). Many responses of the animal will have both a behavioural and a physiological component, which interact, and there will be a continuum from minor to major responses depending on the situation. However, sometimes the behaviour and/or physiological response may be of such a magnitude and/or duration that it has consequences that can be measured using other indicators. Examples of these include weight loss or ceasing to reproduce (production indicators). There may also be changes which affect the animal's health, such as immuno suppression and physical injury (health indicators).

When these indicators are viewed together it is possible to get an estimate of how much effort the animal is putting into coping with a situation.

1.4.1 Health Indicators

The welfare consequences of disease not only depend on the incidence (risk) of disease, but also on the duration of the disease and the intensity of pain or discomfort which a diseased animal experiences (Willeberg, 1991). Thus, long-lasting and chronic conditions are more serious than acute episodes of short duration for the same intensity of pain or discomfort. It seems quite obvious that health, which is equivalent to freedom from disease and injury, is an important part of welfare and an important criterion in the assessment of the quality of life of laying hens. It is, however, important to be aware of the fact that the border between health and disease is often indistinct. For example, should a hen with a small number of roundworms be classified as a healthy hen? A month later the number of worms may have increased 10-fold, and the hen would then undoubtedly be classified as unhealthy.

It is also important to realize that an unhealthy hen does not necessarily experience pain or distress. For example, a hen with weak wingbones may not experience pain, but pain would be experienced if the hen fractures the wingbone. Weak wingbones thus create a welfare risk since the bones of many hens may be broken during handling and transport.

A simple conclusion is that a clinically or subclinically unhealthy bird either already has its welfare reduced or is at risk sometime in the future of having its welfare reduced. A bird that is clinically healthy, however, does not necessarily have good welfare because there may be other welfare problems not affecting health.

1.4.2 Production Indicators

One of the main problems in using productivity as a measure of welfare is that productivity may mean different things such as the average production of a flock, the production per unit of food intake, the economic return per unit of capital or per unit of labour etc. (c.f. Duncan and Dawkins, 1983). No economic measure should be used when assessing welfare and, to be valid, assessment of production should reflect the performance of individual animals, not flocks, although in commercial practice only figures from flocks of birds are usually available. Comparisons may be difficult also because production is influenced by the strain and age of the bird, and can be manipulated by management strategies, such as the lighting programme or the nutritional content of the feed. An extremely high level of production may even predispose the bird to production diseases, such as cloacal prolapse, and so increase the risk of reduced welfare. Nevertheless, under controlled conditions relative changes in the production may indicate changes in welfare.

A simple conclusion is that a sudden drop in production from a high level to a low level probably indicates a welfare problem. However, as with health, good production does not necessarily indicate good welfare.

1.4.3 Physiological Indicators

The most frequently measured physiological indicators are those associated with the stress response and the activity of the hypothalamo-pituitary-adrenocortical (HPA) axis. In poultry, this has typically involved measuring heart rate, corticosteroid concentrations, adrenal gland weight and responses to ACTH challenges. However, as with the other measures, there are difficulties in interpreting the results. The implication is the greater the stress response, the poorer the welfare. In some cases this is true, but not always. Physiological responses to short-term stressors may be different from responses to long-term stressors because the system adapts when stress is prolonged. Furthermore, some of the stress responses can be elicited by positive experiences such as excitement. It is therefore too simplistic to equate an increase in stress with a decrease in welfare.

To resolve this problem, some scientists suggest that there is a welfare problem when the stress response is of such a magnitude that it results in biological costs to the animal and the animal enters a prepathological state. Moberg (1996) argues that instead of measuring the stress response we should be measuring the consequences of the stress, such as suppression of the immune system and failure to ovulate. While there are difficulties in interpreting measurements of HPA activity, entering a prepathological state clearly has an impact on the welfare of the animal.

There are no simple conclusions but, used appropriately, physiological indicators can provide a sensitive measure of animal welfare in terms of measuring the effort put into coping with a situation.

1.4.4 Ethological Indicators

The advantages of ethological indicators, that is studies of animal behaviour, are that they are non-invasive and may precede other indicators. Ethological studies are of three main types:

a) In the first type, birds are placed in the environment under investigation and their behaviour is compared with that of birds either under feral conditions or in an environment assumed to be ideal. This type of study has been used extensively and shows that, in battery cages, some behaviour patterns are observed more and others less often than in the other condition. The problem with this approach is that it is not immediately obvious whether a particular behaviour, or change in behaviour, is an indication of regulatory disturbance or failure, or whether it is an appropriate adaptation to a change in environment. When the behaviour patterns have obvious detrimental effects, as is the case for feather pecking (Blokhuis, 1989), the interpretation of results is easy, but in other cases it is not. For example, Fölsch (1980) found differences in locomotion and acoustic behaviour of hens placed in different environments. But to use such parameters to demonstrate poor welfare, it must first be shown that these changes indicate frustration.

b) The second method is to give birds access to more than one environment and assume that they will choose the environment that is in their best interest (e.g. Hughes and Black, 1973; Dawkins, 1976; Rutter and Duncan, 1991; 1992). Closely related to these choice experiments are operant conditioning techniques in which birds have to work to obtain, or to avoid, some aspect of their environment. (Dawkins, 1983; Meunier-Salaün and Faure, 1985; Lagadic, 1992). Also, demand functions can be generated by making animals perform a variable amount of work in order to obtain the same amount of reward (Dawkins, 1983; Ladewig and Mathews, 1996).

Poorly designed preference tests have been criticised (Duncan, 1978) and operant conditioning is considered by some to be a problematic way of measuring animal motivation (Dawkins and Beardsley, 1986). However, others consider these to be the most powerful tools available for studying the behavioural needs of animals, even if some caution should be taken in the interpretation of results (van Rooijen, 1982; Ladewig and Mathews, 1996).

c) The third type of ethological method used to assess welfare is to observe behaviour in experimental situations and compare this behaviour with the behaviour in the environment under study. In a situation where the animals do not appear to be coping or cope only with great difficulty, several behavioural changes may be apparent, some of which may be called abnormal or stereotypic (e.g. Wiepkema, 1985). Although there is some controversy on the exact meaning of stereotypies (e.g. Cooper and Nicol, 1991; Dantzer and Mormède, 1981; Mason, 1991; Savory, 1989; Wiepkema, 1987), it is generally thought that suffering occurs before stereotypies are established.

The apparent simplicity of ethological studies can lead to them being misused. However, as with physiological indicators, when used appropriately ethological indicators can be a sensitive measure of animal welfare.

1.5 Combining Results from different indicators

It is agreed that there is no single indicator of animal welfare and that to get the best indication, several different measurements have to be taken. In some cases, all indicators, be they health, production, physiological or ethological, point in the same direction and the interpretation is clear. More often, there are conflicting results (Mason and Mendl, 1993).

Another problem in the evaluation of animal welfare is the lack of knowledge of how animals experience, for example, the states of disease, conflict behaviour or abnormal behaviour. Are some states more important from a welfare point of view than the others? These questions are difficult to answer with our present knowledge of veterinary and ethological science. An alternative view, therefore, is that of Fraser (1995) who proposed that instead of attempting to "measure" animal welfare, the role of science should be to rectify and prevent welfare problems.

Rushen and de Passillé (1992) acknowledged the problems in measuring welfare and proposed that criteria for assessing welfare can be divided into design criteria (which specify what must be included in an animal's environment to promote good welfare e.g. space allocations etc.) and performance criteria (which indicate what parameters of the state of an animal indicate good or poor welfare e.g. production performance, physiological indicators of stress etc.). They propose that housing can be assessed using an optimum mix of these two criteria.

1.6 Summary

Despite there being no single definition of animal welfare, scientists do agree on many of the basic principles. For example, many agree that welfare is ultimately about what an individual animal feels, but think that the techniques to measure feelings are not very well developed at the present time. Techniques to measure the effort an animal is putting into coping with a situation are better developed and, since this should be correlated with feelings, it is argued that current research should concentrate on these measures as indicators of welfare. The most commonly used welfare indicators are measures of health, production, physiology and ethology. Any one of these indicators may be used on its own to indicate poor welfare, but an integrated (Smidt, 1983) or holistic (Simonsen, 1996) approach gives a better indication of the effort the animal is putting into coping and hence the biological cost to the animal of responding. With regard to assessing housing for animals, recent thinking supports a balance between design and performance criteria and focusing on specific welfare problems.

CHAPTER 2

HOUSING SYSTEMS FOR LAYING HENS

2.1 Introduction

The debate on animal welfare in many countries, and in particular the criticism of laying cages - the most widely used egg production system, has stimulated many developments in the enhancement of cages, improvements to existing alternatives and the emergence of new designs.

Since no country in the EU has yet phased out laying cages, these developments have generally been gradual and well thought out. The phasing out of conventional cages in certain countries (or the proposal to do so) has stimulated the production and testing of several alternative systems, some of which were already under development. In certain countries premium markets for deep litter, barn and free range eggs have been developed on a considerable scale, encouraging the use of alternative systems.

In such projects management as well as system design are important for good performance and bird welfare. Common problems such as floor laying, feather pecking and cannibalism may be reduced to some extent by a judicious combination of efficient design and husbandry skill; it has to be said that although feather pecking is common in caged layers, cannibalism seems to be a problem much less frequently in cages, and that a better understanding of the underlying causes of some behaviours e.g. feather pecking and cannibalism might assist in the design and management of alternative production systems (Hughes, 1990).

2.2 Laying cages

The laying cage is usually a small enclosure with a sloping floor and ancillary equipment for feeding, drinking and egg collection mounted on the front. It may appear that little change has taken place during the past 40 years since battery cages took over from traditional systems as the most popular system of egg production. However, in recent years there have been several changes in the detail of cage design and construction to improve production efficiency and enhance bird welfare.

One of the major points which has given rise to public concern is the degree of confinement of laying hens in cages. In several countries the area allowed per bird in cages has increased and indeed Directive 88/166/EEC has helped to achieve this. However, a wide range still exists in multi-bird cages, from under 350 cm^2/bird in the USA to 450 - 500 cm^2/bird in most of the EU and 600-700 cm^2/bird in Scandinavia. Following the introduction of national laws from 1988 onwards implementing Council Directive 88/166/EEC in the various Member States, most manufacturers redesigned their cages and in doing so allowed more area per bird.

A very common cage size now offered by most major cage manufacturers in Europe is 50 cm square giving a cage area of 2500 cm^2. When stocked, as most currently are, with 5 birds such cages provide 500 cm^2/bird. However, the Directive states that "at least 450 cm^2 of cage area, measured in a horizontal plane which may be used without restriction, in particular not including non-waste deflection plates liable to restrict the area available, shall be provided for each laying hen". There is a difference of interpretation of what constitutes "cage area............which may be used without restriction" in different Member States especially in relation to the areas occupied by deflection plates and other protrusions such as drinker pipes and drip troughs. In practice, deflection plates are fitted immediately behind the feed trough and generally protrude about 5 to 10 cm into the cage. In the national laws of Belgium, Germany, the Netherlands, Sweden and the UK the area occupied by the deflection plate can be included as cage area but in those of France and Italy it cannot. In our view, the area occupied by such deflection plates allows most behaviours found in cages and should therefore be included in the cage area. However, information is lacking as to whether other equipment in cages which protrudes below the required height interferes with normal bird activities in the area occupied by that equipment.

Council Directive 88/166/EEC as well as requiring certain minimum space allowances lays down several requirements for design and constructional factors. The first of these is "the form and type of materials employed for constructing the cages and the construction and characteristics of the latter must be such as to prevent any injury to the animals to the extent possible in the existing state of technology". Tauson (1985) has demonstrated several potential traps in cages, and how they may be avoided. It is difficult to completely eliminate trapping points for such parts of the bird's anatomy as the comb, wattles, head, wings and flight feathers, toes and claws. However, many modern cages have much improved design in this respect and in particular V traps can be avoided, such as that which opens when a floor sags away from a side partition. The solution is to take the side partition down below the floor, or to fix it closely and positively to the floor.

One part of the bird which is easily trapped in narrow gaps between cages parts (which are difficult to eliminate) is the claw. Claws of some caged birds grow quite long to 2 or 3 cm during the laying year and become very sharp or sometimes broken. Work in Sweden and the UK (Tauson, 1986; Elson, 1990a) has demonstrated that the provision of abrasive strips or surfaces of a controlled width on the baffle plates behind feed troughs shortens and blunts the claws on the 3 forward facing toes, thus effectively eliminating this welfare problem. The technique, although not widely used commercially, has been well tested, and is currently required by legislation in laying cages in Sweden.

Council Directive 88/166/EEC requires that "floors of battery cages must be constructed so as to support adequately each of the forward facing claws of each foot". In practice this means that the rectangular mesh of floors should probably be not greater than about 50 mm by 25 mm where the bird stands. Most cage floors are constructed of rectangular welded wire mesh and galvanised or otherwise treated to give them durability and a smooth finish.

Council Directive 88/166/EEC requires that the slope of such floors shall nor exceed 14% or 8° but allows Member States to permit steeper slopes for floors using other than rectangular mesh.

Perches are not yet widely used in commercial cages except in Sweden where they are compulsory, but are the subject of research and have been shown to work best when fitted near the back of the cage (Appleby and Hughes, 1990); the design of the cage back must be fairly open to avoid manure clogging there. The provision of one perch across the width of a cage is generally insufficient at the currently permitted maximum stocking density (450 cm^2/bird) since this usually only amounts to about 10cm/bird, so that all birds cannot perch at once. However, when at least 12 cm of perch length/bird was provided, Leghorn type strains of bird could all perch simultaneously (Tauson, 1984). When installed, perches in cages are very well used, especially at night.

Cage fronts have improved to meet the requirements of paragraph 2 in the Annex to Directive 88/166/EEC. They are now usually constructed of horizontal bars which reduce trapping and feather wear and facilitate easier inspection and improve feed trough access. Fully opening cage gates which allow almost the whole of the cage front above the feed trough to open (except for constructional margins) are now available on several makes of cage (Elson, 1990a). It is anticipated that, together with gentle handling, this development will reduce bone breakage when cages are depopulated.

Laying cages may be arranged in various configurations within a battery unit from flatdeck (single tier) through stepped and semi-stepped layouts several tiers high to vertical arrangements, usually with cages back to back from 3 to 8 tiers high. The Annex to Council Directive 88/166/EEC requires that "accommodation comprising more than 3 tiers of cages shall be permitted only if suitable devices or measures make it possible to inspect all tiers without difficulty". Whilst various items of equipment (e.g. trolleys, steps, rails) have been used to this end, they are often unsatisfactory. A fixed catwalk or gangway halfway up a 6 tier block of cages, making them effectively 2 sets of 3 tiers one above the other, is much more satisfactory. Furthermore a minimum aisle width between cage blocks of about 1 metre is required for adequate bird inspection in all tiers, and for minimisation of damage on depopulation. Such an aisle width would allow transport containers to be taken right to the cages thus further reducing handling damage.

2.2.1 Enriched cages

GET-AWAY CAGES

Efforts have been made to provide perches, nest boxes and dust baths in laying cages. One approach is the get-away cage developed by Elson (1976) in which birds have perches, feeders and drinkers at 2 levels together with a flat wire mesh floor and adjacent nest boxes. Performance in these cages was similar to that in conventional ones, but there were some management and hygiene problems. Workers in several other countries developed the get-away cage further (Wegner, 1990). It generally now has a sloping floor, rollaway nest boxes and no dust bath (unless the latter has controlled opening times). Get-away cages are generally much larger than conventional ones, and accommodate larger colonies of between 10 and 40 birds. Although widely studied in research centres, they have never come into widespread commercial use.

ELSON TIERED TERRACE (ETT)

A novel concept, in which an attempt has been made to preserve the good control and sound technology of cages, whilst allowing the birds much more freedom, is the terrace system. Tiered, slightly sloping wire mesh floored terraces are interconnected by a stairwell giving controlled access in the afternoons to a littered ground floor area. Feed, water, nesting and perching facilities are provided on each terrace, so that birds return to them at night via one-way gates. This system was tested in England and Germany (Elson, 1989). It did not unfortunately prove successful; feather pecking and cannibalism were the main problems, probably due to aggression when birds from the terraces mixed on the staircase and litter area in the afternoon. A similar terrace system but without the interconnecting stairwell is being studied at Spelderholt in the Netherlands. It is called a family cage and holds from 35 - 48 hens (Niekerk and Reuvekamp, 1995 a & b). Several large cage types were developed and tested in Switzerland in the early 1980's but none were successful (Oester, 1986).

MODIFIED ENRICHED CAGES(MEC's)

The development of MEC's has been aimed at retaining the benefits of good control and stable social order found in small groups of four to eight birds in standard laying cages (Ekstrand and Keeling, 1994). The object has been to allow a greater behavioural repertoire to be displayed in cages which have been enriched by the provision of more space (height and area), perching and nesting facilities and possibly a dust bath and claw shortener. Such laying cages are usually about double the size of conventional ones.

The first was the Edinburgh Modified Cage (Appleby, 1993). The Edinburgh project commenced in 1988 and compared five prototype cages with conventional cage controls (Robertson *et al.*, 1989). It adopted a stage by stage systematic approach to enriched cage design. The final version incorporated a perch, a nest box, a dust bath and increased area and height.

Workers at other centres in the UK, Sweden and the Netherlands took up this work; their early studies and conclusions were reported at a symposium in London organised by Sherwin, 1994: see also Hughes (1993), Reed (1993) and Abrahamsson (1996).

Some MEC's are mechanised so that a nest box is open only in the morning and a dust bath only in the afternoons. Others are simpler allowing birds access to the nest at any time. Few birds sleep in the nest boxes since the perch is more attractive to them. Conversely few eggs are laid (and damaged) from the perch when a nest box is provided, since most eggs are laid in it. Some simplified versions of MEC's do not provide a dust bath; where one is provided the litter (various types have been tried) is often quickly scratched out and needs frequent replenishment which is time consuming and/or expensive.

A major four year scaled up study involving six designs of MEC and two stocking densities is now underway at Gleadthorpe Poultry Research Centre in England. The first year's experiment is now complete and the results are encouraging. In the best treatments performance was good, perches and nest boxes were well used and levels of dirty and damaged eggs were acceptable at two stocking densities - 5 (1000 cm^2/bird) and 7 (714 cm^2/bird) brown medium hybrid layers. In the second study a colony size of 8 birds/cage (625 cm^2/bird) has been added. These areas include that provided by nest boxes to which birds have continuous access.

Similar encouraging results have been achieved in Sweden with small groups of both white and brown laying strains (Abrahamsson *et al.*, 1995); at the Funbo-Lovsta Research Centre studies are continuing and the latest showed no major differences between groups of 5 and 8 birds per cage at 600cm^2/hen. In the Netherlands, Niekerk and Reuvekamp (1995a & b) are involved in on-going studies of various levels of enrichment in small cages holding from 5 to 10 white and brown hens. Enrichment includes various combinations of perch, scratching pad, nest and dustbath.

A few egg production companies in Britain are now trying out MEC's of various prototypes on a larger scale, but they are not yet in commercial use.

2.3 Non-cage egg production systems

Several alternative systems to cages have been developed over the past 20 years, although some, e.g. deep litter and wire and slatted floor systems, were in use before that, and have also been used for breeding stock during that period.

A review of alternative systems to cages for laying hens was presented by Wegner (1986). A range of alternative production systems to cages was described briefly by Elson (1988b) and more fully in illustrated papers by Elson (1989) and Elson (1990b). A CEC Seminar held in the Netherlands reviewed alternative systems of egg production to cages; the proceedings were published (CEC 1989). An updated description of the various systems follows. Figures 2.1 to 2.8 illustrate several types of alternative systems to cages: they are reproduced from Elson (1995a). It should be noted that all non-cage systems provide the birds with nests for egg laying, and in many litter is provided as well as perches or platforms.

2.3.1 Indoor systems

Such systems may be of one floor, or several levels. McBride (1970) theorised that "it should be possible to design houses which have many tiers of lattice floors". A few years later such systems were proposed and tested. They include aviaries and percheries.

AVIARIES

Elson (1976) and colleagues in the UK designed a system which enabled stock to make better use of the volume of the building than is possible with deep litter (Hill, 1981 a and b). Several tiers of perforated platforms were built into the system, interconnected by ladders - see figure 2.1. These platforms may be constructed of wire or plastic mesh, or wooden slats and feed, water and nest boxes are provided at all levels. Stocking density varies from about 15 to 25 birds/m² depending on the number of tiers of platforms provided.

Several types of aviary were also studied in other countries especially Germany, the Netherlands, Switzerland and more recently Scandinavia (Abrahamsson and Tauson, 1995; COVP, 1988; Elson, 1991; Ehlhardt *et al.*, 1984; Gunnarsson *et al.*, 1995; Hansen, 1990; Hultgren, 1989; Oester, 1986; Tauson and Jansson, 1991 and Wegner, 1986). In some of these manure scrapers or belts have been installed under the perforated platforms, so that birds living in the lower areas keep clean, and a better environment can be maintained in the building by regular manure removal.

Detailed studies in The Netherlands during the 1980s led to the development of a type of aviary called the TIERED WIRE FLOOR (TWF) system for laying hens (Ehlhardt *et al.*, 1989). In this system the birds have access to a littered floor from 3 tiers of wire platforms. Feed is available on the 2 lower platforms and water on all 3. Perches are mounted over the top tier - see figure 2.2. A stocking density of about 20 birds/m² (similar to a house with 3 tiers of vertical cages) has been achieved with the TWF system. Manure belts run under the wire platforms. This system is now being used in the Netherlands on a commercial scale, (Blokhuis and Metz, 1995).

The Swiss aviaries also have manure belts or scrapers, and are similar to the TWF aviary, but are generally more compact. Like the TWF system they incorporate a resting area, a feeding and drinking area, a nesting area and a scratching area (Oester, 1986). Examples of the Swiss approach include NATURA (figure 2.3), MULTIFLOOR (figure 2.4), BOLEG 2 and VOLETAGE systems. The maximum stocking density in these Swiss aviaries is 21 birds/m².

Some of these aviary systems have been modified, studied and tested in Sweden. These include LOVSTA, MARIELUND, OLI-VOLETAGE and VENCOMATIC (Algers, 1993; Abrahamsson and Tauson, 1995).

A development of the compact belted aviaries took place in 1990 in the UK, and resulted in the development of the NATUREL aviary (Elson, 1991). In this version feed, water, nest boxes and resting areas are provided at all 3 levels and birds only have to come down to scratch or dustbathe in the litter on the ground floor. The rationale behind this system is that when birds are given freedom of movement but housed on several levels at fairly high densities (15 to 25 birds/m²), it is necessary to provide for most of the behavioural activities at all levels so that performance is maintained, and birds living in specific areas of a house are not deprived.

PERCHERIES

In the German work on aviaries an arrangement of perches as well as platforms was used. The perchery system was developed by Michie and Wilson (1984) in Scotland and also in Germany (Rauch, 1991a). This system consists of several tiers of perches mounted on an A Frame and has narrow slatted platforms at the top with feeders and drinkers at most levels - see figure 2.5. Litter is provided and performance has been excellent when stocked at 17 birds/m². Subsequently the Gleadthorpe perchery was developed (Alvey, 1989). In this slatted platforms are eliminated, and care has been taken to arrange perches to give easy access to nest boxes at all levels and to minimise manurial contamination of birds at lower levels. Feed and water are also provided at all levels, and litter on the ground floor level only - see figure 2.6. In commercial versions in large deep-pit houses, litter is often eliminated to reduce floor egg problems and higher densities of up to 25 birds/m² are employed, always allowing at least 15 cm of perch space per bird.

Less intensive approaches (with lower stocking densities) include the covered strawyard, deep litter and perforated floor systems.

STRAWYARDS

The covered strawyard was described by Sainsbury (1981), and studied during the early 1980s in the UK (Gibson *et al.*, 1986). This is a low stocking density system with much freedom, low winter temperatures and high production costs. It is usually uninsulated, and relies on the use of deep straw frequently replenished to maintain adequate litter conditions.

DEEP LITTER

The deep litter system allows a moderate stocking density of about 7 birds/m² while still maintaining birds mainly at a single floor level on wood shavings, chopped paper or straw, sand or other litter material (Appleby *et al.*, 1988a). Raised, perforated platforms are often added, but these do not usually increase the floor area. Part litter/part perforated floor systems are stocked at from about 7 to 11.7 birds/m². Many such systems have been installed in various Northern European countries. They are generally easier to manage than deep litter and often perform well, although feed intake can be high during the winter. In one version, the "belted roost raft", the birds have access below the platforms which have manure belts under them, and this allows stocking density to be further increased.

PERFORATED FLOOR SYSTEMS

These may be constructed of wooden slats or plastic or wire mesh floors. In some such systems birds are prone to flight en masse ("hysteria") when disturbed. The Hans Kier system developed in Denmark is a modified sloping wire floor system with perches in which birds have controlled access to an area of sand during the non-laying part of the day (Nørgaard-Nielsen, 1986) - see figure 2.7. The birds' freedom is increased, and stocking density is moderate at about 10 birds/m² - similar to modified deep litter systems.

Stocking density

In alternative systems to cages where birds are loose housed, much more 3 dimensional space can be available than in cages by the use of the volume of the building, as well as increased area on elevated platforms or perches (table 2.1), and birds have greater height available for wing flapping, flying etc. Recommendations on space allowances in colony systems were made by the British Farm Animal Welfare Council (FAWC, 1991). Further recommendations have since been made in Britain by the RSPCA (1995) and in the Netherlands by the Commodity Board for Poultry and Eggs.

It may be useful to consider some of the perchery and aviary systems in current use, and to note that even at a high stocking density of 25 birds/m² (400 cm²/bird) on a ground floor area basis, the available surface area or equivalent (excluding nest boxes) allows between 813 and 1020 cm²/bird (9.8 to 12.3 birds/m²). At 20 birds/m² on a ground floor area basis, available surface area is 1020 to 1389 cm²/bird (7.2 to 9.8 birds/m²).

Such figures are generous compared with anything contemplated for hens in laying cages, especially since they exclude the nesting area to which birds in alternative systems have access, at least during the day. Figures for stocking density in the available surface area, including and excluding nest boxes, and on a volume basis, are given in the following table:

Table 2.1. Stocking density in some Egg Production systems

SYSTEM	IN GROUND AREA (birds/m^2)	IN TOTAL SURFACE AREA (birds/m^2) (1) EXC. NEST	INC. NEST	IN TOTAL SPACE (birds/m^3) (2)
Cage - 3 tier	24	20.0	--	10.0
Cage - 4 tier	32	20.0	--	10.6
Cage - 6 tier	48	20.0	--	11.4
Cage - 8 tier	64	20.0	--	11.9
Naturel 90 Aviary	25	9.0	8.3	11.4
Naturel 90 Aviary	20	7.2	6.6	9.1
Natura Aviary	25	10.9	9.6	11.4
Natura Aviary	20	8.7	7.7	9.1
Multifloor Aviary	25	12.3	10.9	11.4
Multifloor Aviary	20	9.8	8.7	9.1
Boleg Aviary	25	11.2	10.1	8.3
Boleg Aviary	20	9.0	8.1	6.7
Dutch TWF Aviary	25	10.9	10.0	8.3
Dutch TWF Aviary	20	8.8	8.0	6.7
Marielund Aviary	17	8.8	7.4	7.7
Gleadthorpe Perchery	25	11.6	10.0	8.3
Gleadthorpe Perchery	20	9.3	8.0	6.7
Deep Litter	7	7.0	6.4	2.9

Equipment

There are no common standards in the provision of equipment: however, it is generally recognised that in respect of nest boxes (individual or communal) feeders (chain or pan) and drinkers (bell, nipple or cup) an even distribution of equipment is important as well as an adequate provision (e.g. one individual nest per 5 - 8 birds, communal nests at 100 - 120 birds/m^2, 10 cm of feed trough or 4 cm of circular feeder per bird and 1 nipple or cup drinker per 10 birds).

2.3.2 Outdoor systems

Outdoor systems provide access outside and include those with fixed houses and alternately used outdoor pens - see figure 2.8 and those with small houses providing sleeping accommodation, shelter and nest boxes frequently moved over the land, or lightly

[1] or equivalent: where this is provided as perches it has been assumed for the purposes of calculation that each 15 cm of perch length is equivalent to 450 cm^2, provided that the perches are at least 30 cm apart.

[2] To calculate stocking density in total space (birds/m^3) it has been assumed that buildings are a mean of 2.2 m high for Naturel, Natura & Multifloor aviaries, 2.4 m for 3 tier cages and deep litter, 3 m for Boleg, TWF, and Marielund aviaries, Gleadthorpe perchery and 4 tier cages, 4.2 m for 6 tier cages and 5.4 m for 8 tier cages.

constructed ones that can be moved occasionally. The term "free range" tends to be used more generally nowadays to describe both of these outdoor systems, but the degree of freedom is greater for birds on true free range (Elson, 1985) where birds at a maximum stocking density of 400 birds per hectare spend most of the daylight hours outside the buildings. However with fixed free range houses and well managed alternating outside grassed pens - see figure 2.8, 1000 birds per hectare can be made to work and gives birds considerable freedom, although they generally spend far less time outside, and some birds probably never go out.

Both systems are classed as free range under Commission Regulation (EEC) No. 1274/91, which introduced detailed rules on marketing standards for eggs (E.C., 1991), as long as the maximum stocking density on the land does not exceed 1000 hens per hectare. Under this Regulation, such a system may be called "semi-intensive" if this maximum stocking density is over 1000 hens per hectare but does not exceed 4000 hens per hectare.

Housing for free range systems can include any of those described above except cages and terraces. It could be argued that there should be a maximum flock size for each free range house (say 4000-5000 birds) and an agreed provision of popholes of certain minimum dimensions - say at least 2 m wide by 0.5 m high, and the equivalent of one pophole of 0.25 m^2 per 250 birds (i.e. 10 cm^2/bird), to ensure that birds have freedom to leave the building and return to it at will, during daylight hours.

2.4 Design and management of alternative systems to cages

Design and management have interactive effects and excellence in both is required to achieve economic performance and good welfare. Layout of equipment within pens has important effects especially where high densities occur, and researchers have been able to improve access to furniture by careful layout design. Water is best provided over raised platforms, where fitted, rather than over litter, especially where manure is regularly removed by conveyors. Wire mesh platforms keep cleaner than wooden slats, and plastic mesh generally comes somewhere between the two.
As shown by Rietveld-Piepers (1987) and Appleby *et al.* (1988b) the material and design of nest boxes have important effects on the degree of use by birds and consequently the proportion of floor (and dirty and broken) eggs. Nest boxes constructed of wood, with a litter nesting material and a firm alighting rail close to the nest tend to be preferred and generally give the fewest floor eggs. Birds show a preference first for litter nesting material followed by artificial turf and perforated plastic floors and then plastic mesh over wire. Litter can be inserted in most types of nest box for the first few days to encourage their maximum use, thus reducing floor eggs. Other techniques like the use of decoy eggs or leaving a few eggs in each nest after egg collection can be management aids. Rearing in a non-cage system and early removal of eggs laid on the floor are also important.

Additional measures apply to free range housing. Small houses should be moved frequently to aid pasture management. If fixed houses are used, they should preferably be long and narrow to allow access to several outdoor pens; birds can thus be frequently allowed onto fresh pasture. Wind baffles should be provided around popholes, and birds allowed out onto a perforated platform (preferably covered by a roof overhang) to keep their feet clean and dry. Shelter and shade from the elements and protection from predators should be provided.

2.5 Summary

Public concern for animal welfare together with the need for increased production efficiency have stimulated much applied research into egg-laying systems in recent years. This has included improvements in the design of laying cages and the development and modification of a whole range of alternative systems to cages from modified enriched cages through high-density systems like aviaries, percheries and lower density alternatives such as deep litter to extensive systems such as semi-intensive and free range.

Various approaches have been initiated by workers in different countries. In the European Union many of the research projects have run for several years, and reports have been submitted to the Commission or the work reported at EU seminars (CEC, 1989 and CEC, 1992).

In such projects, management as well as system design are important for good performance and bird welfare. Common problems such as floor laying, feather pecking and cannibalism can sometimes be reduced by a judicious combination of efficient design and husbandry skill. A better understanding of the underlying causes of some behaviours, e.g. feather pecking and cannibalism, would assist in the design and management of alternative egg production systems.

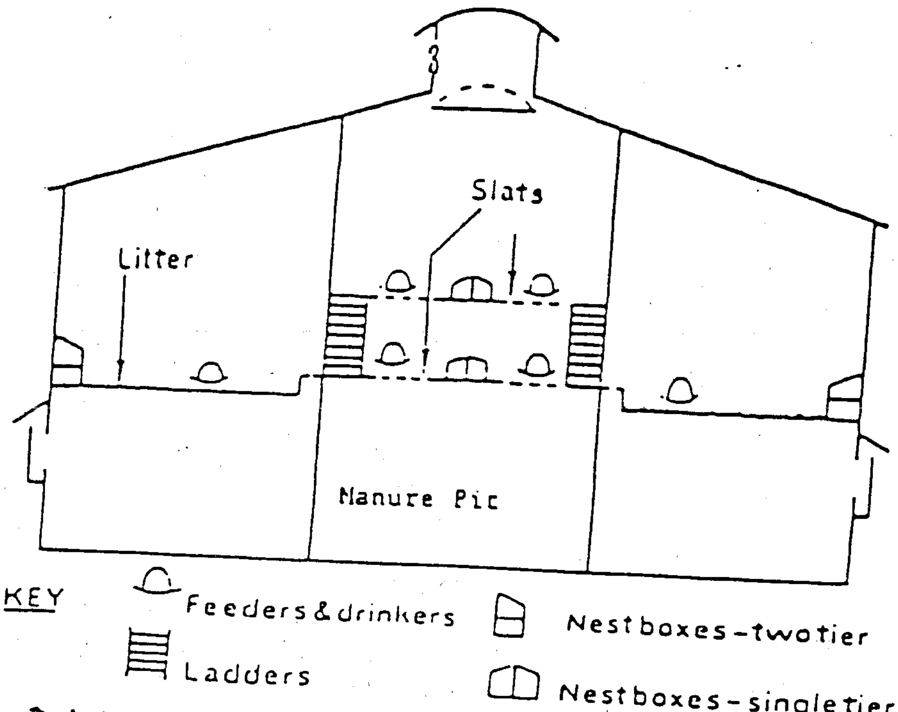


Fig 2·1. Aviary system.

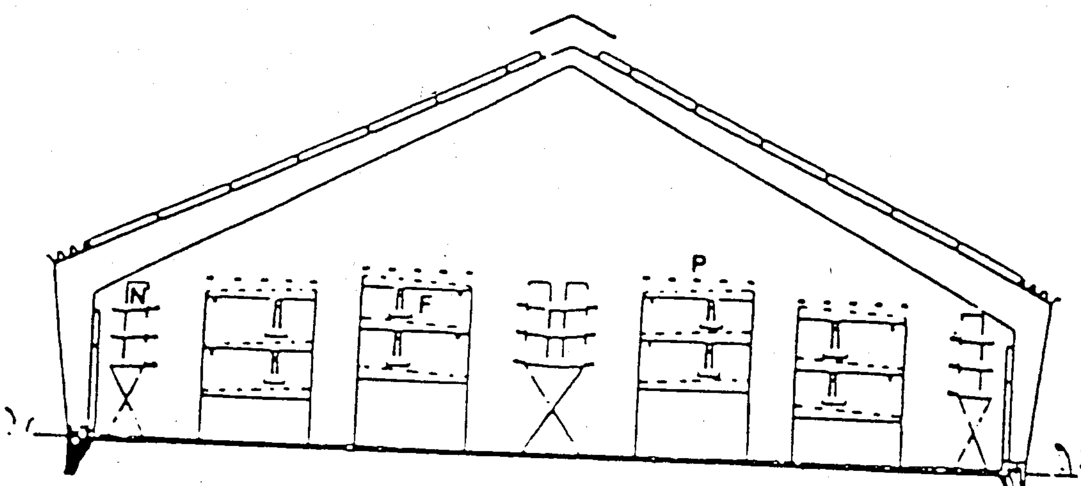


Fig 2·2. Tiered wire floor (TWF) aviary.

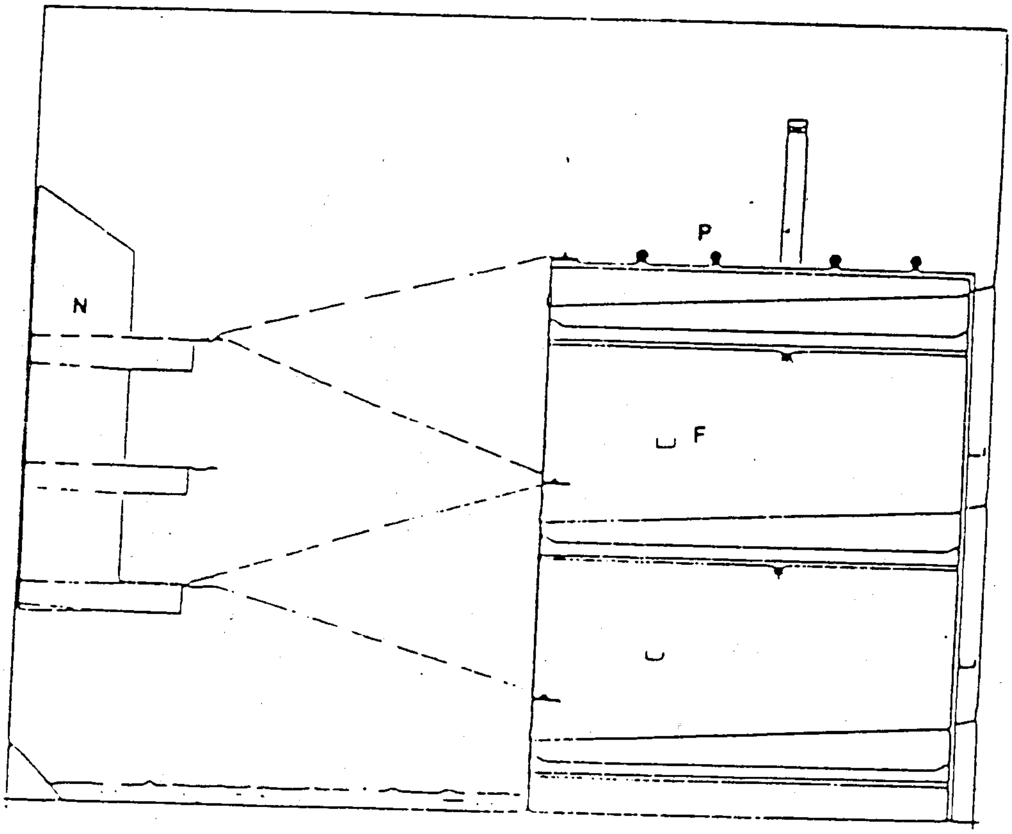


Fig 2-3. Natura system

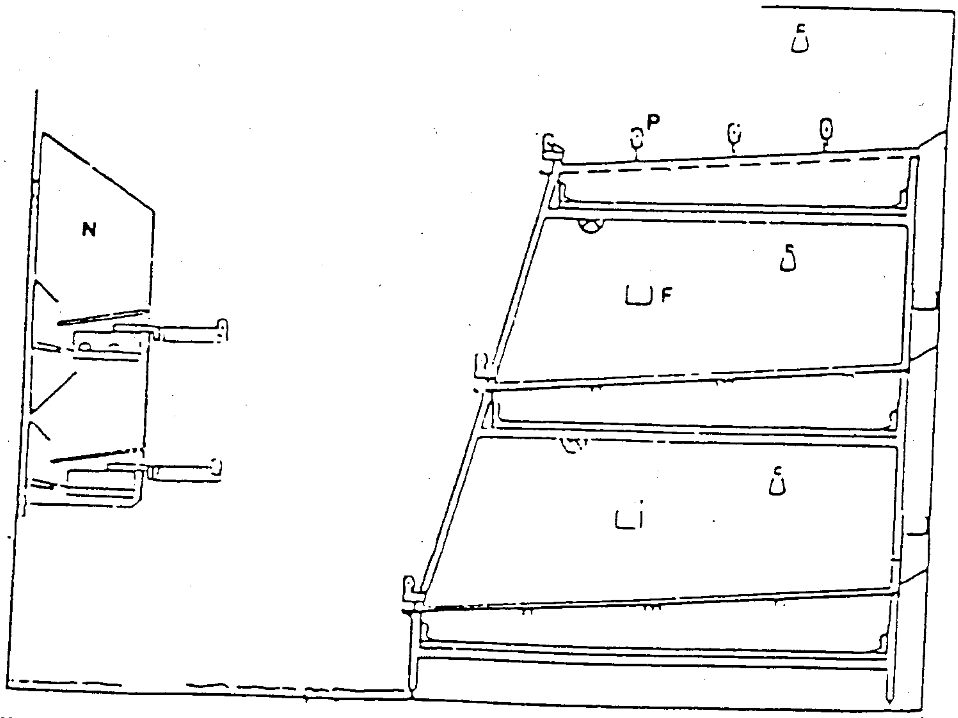


Fig 2-4. Multifloor system

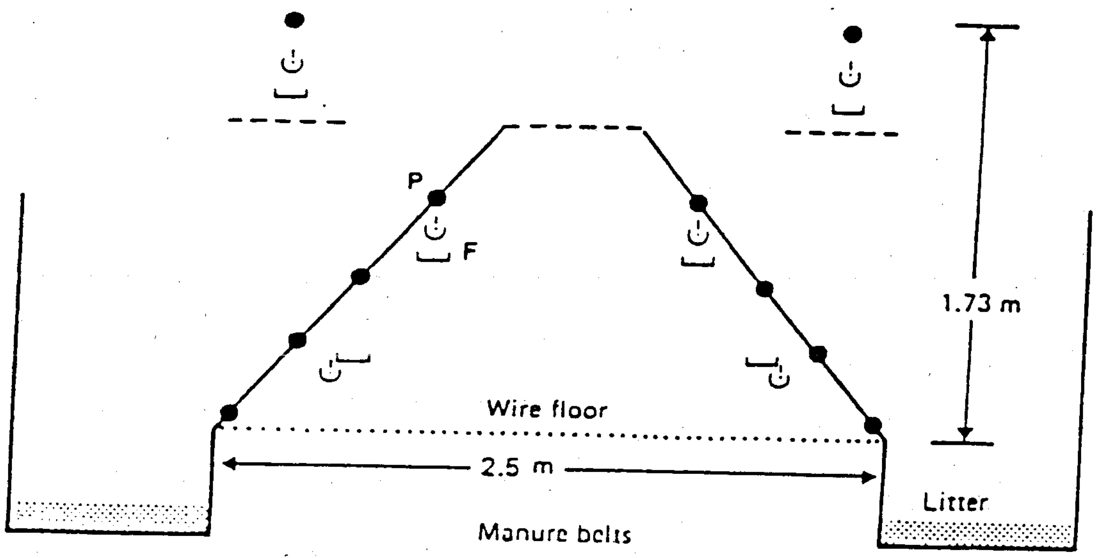


Fig. 2·5. Michie perchery.

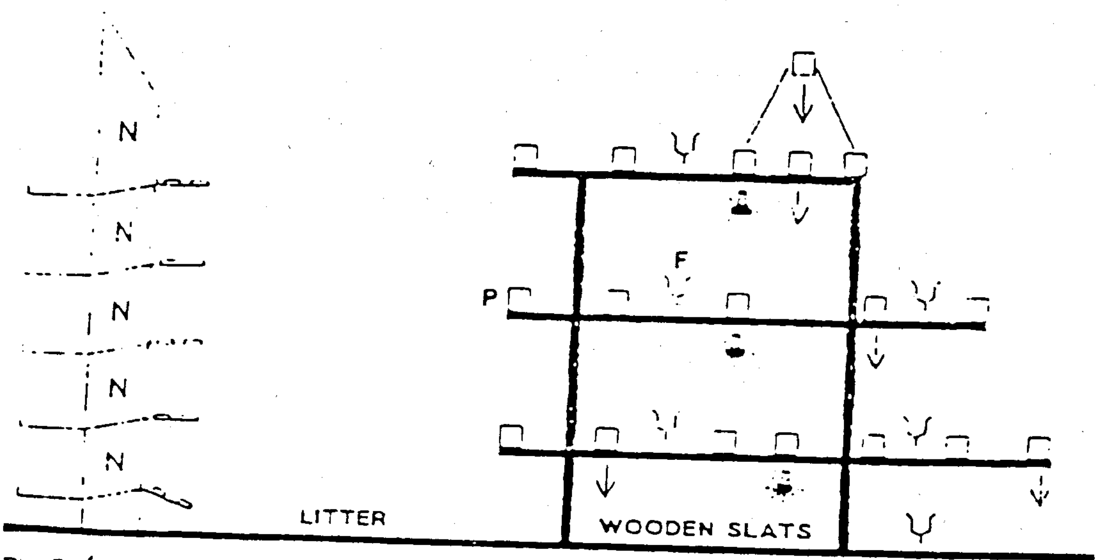


Fig. 2·6. Gleadthorpe perchery.

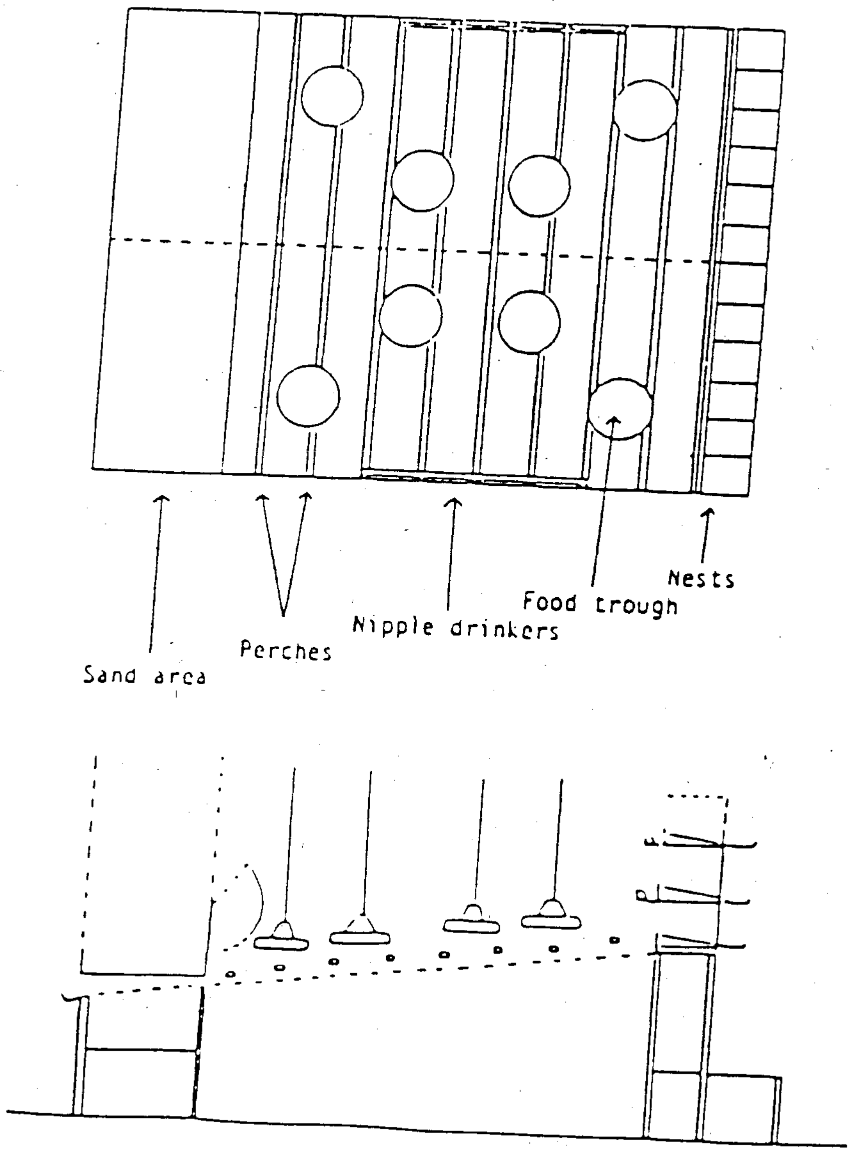


Fig. 2·7. The Hans Kier system

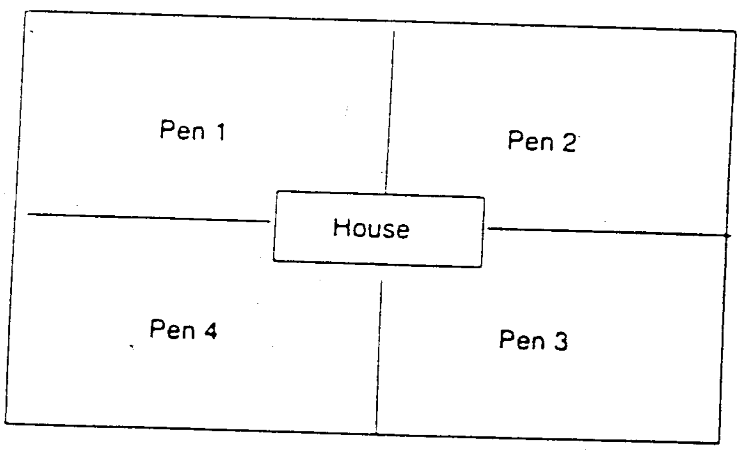


Fig. 2·8. Fixed free range house with alternating pens.

CHAPTER 3

SPECIFIC ASPECTS OF HOUSING

3.1 Behaviour and physiology

Behaviour and physiology are good indicators of the adaptation process and thus can be and are used as indicators of the state of adaptation. Some behaviour patterns expressed in the normal repertoire of the animals have little or no adaptative value in domestic conditions (fear reactions and aggression) but are also indicators of welfare particularly if abnormally high. Some other behaviour patterns that are rare or absent in natural conditions can be far more frequent in domestic conditions. They can be the indicators of welfare problems (stereotypies) but also the source of welfare problems (feather pecking and cannibalism). Behavioural and physiological parameters are also probably the most sensitive indicators of welfare.

3.1.1 Space allowance per bird

The question of what space allowance is adequate for the welfare of hens is difficult to answer. One approach to the question is to measure the area covered by hens performing their common behaviour patterns. Such measurements have been carried out (using different techniques) for example by Bogner *et al.* (1979) and more recently by Dawkins and Hardie (1989). In the first study white and brown leghorns were used with an average weight of 1.8 kg. In the second study Ross Brown hens with an average weight of 2.02 kg were used.

Table 3.1. Area (cm^2) covered by hens performing different behaviour patterns.

	Bogner *et al.* (1979)	Dawkins and Hardie (1989)
Standing		428- 592
Turning	-	771 - 1377
Wingstretching	538	653 - 1118
Wingflapping	-	860 - 1980
Feather ruffling	676 - 1604	
Preening	506	814 - 1270
Groundscratching	-	540 - 1005
Feather raising	497	-

The establishment of a minimum space allowance from these data is difficult because factors such as what is in the space and the group size should also be considered. Moreover, in addition to the space used by hens in performing behaviour patterns, space is also needed for locomotion and to allow for social behaviour and inter-individual distances. Therefore, the measurements may be regarded as less than the minimum space needed (Dawkins and Hardie, 1989). On the other hand a bird, when resting, can occupy a very small space and share it.

The important aspect is thus not only space per bird but the effective space which increases as group size increases. As a result small group sizes need more space per hen than larger groups.

Another approach to the problem is the study of hens' behaviour under various housing densities. Studies following this approach often compared the behaviour of hens in cages with that of hens in floor pens (e.g. Bareham, 1972; Black and Hughes, 1974; Jones and Faure, 1981; Otto and Sodeikat, 1982; Wegner *et al.*, 1982). The most prominent and consistent result from these studies is that behavioural patterns which take up a lot of space are less frequent in cages. Obviously this has to do with space allowance and group size (a large group allows individual birds to temporarily take more space than the average per bird). Results from studies where different housing densities were studied in one housing system were not always consistent. However, there is a clear tendency for less disturbed behaviour when the hens are allowed more space (Cunningham *et al.*, 1987; Hansen, 1976; Hughes and Black, 1974; Nicol, 1987; Zayan and Doyen, 1985).

Contradictory results exist for the effect of density on fear responses. High stocking densities (412 compared with 516 cm^2) adversely affect fear level (Sefton and Crober, 1976), and nervousness and feather score (Craig and Milliken, 1989), but for nervousness the effect only appears at a density of 350 cm^2 per bird. On the other hand, Lee and Moss (1995a) found no difference in fear level for hens kept at densities between 390 and 1550 cm^2 (4 to one bird in a 1550 cm^2 battery cage, thus confounding density and group size) when at the same time food consumption or laying rate were affected (Lee and Moss, 1995b). It seems also to influence the incidence of hysteria but in most studies of hysteria density and group size are confounded (Mills and Faure, 1990).

Most of our interpretation of space in laying hens is classically based on the concept of social space as defined by McBride (1970). In this concept "All (the animals) have the property of dominance over an area fixed in the case of territories and portable in hierarchies". In these conditions any space restriction might lead to an overlap between the social space of different birds and thus to stress and aggression. However, the attempts made to measure the size of this social space were unsuccessful and its existence seems to be unlikely (Meunier-Salaün and Faure, 1984; Keeling and Duncan, 1989).

In fact Polley *et al.* (1974) and Al Rawi and Craig (1975) showed that, contrary to the prediction derived from McBride's concept, the level of aggression is not a linear function of density but is highest at a density of 1200 cm^2 (Polley *et al.*, 1974) or 800 cm^2 (Al Rawi and Craig, 1975) per bird and is low at lower or higher densities. This effect is probably due to the decrease in agonistic encounters between pairs of subordinate animals when the dominant is in close proximity, as demonstrated by Ylander and Craig (1980) and Bshary and Lamprecht (1994) and to the possibility for the low ranking animal to escape at low densities. The effect of density on aggression is not however found in all the studies and sometime the two seem to be independent (Doyen and Zayan, 1982). Hens also actively search for contact with conspecifics at least during feeding behaviour and this is also in contradiction with the social space hypothesis (Meunier-Salaün and Faure, 1984; Mills and Faure, 1985).

When given the choice single hens usually prefer a larger cage to a smaller one (Hughes, 1975; Dawkins, 1978; Nicol, 1986) and also prefer litter to wire floor (Dawkins, 1978; 1981).

Hens do work to enlarge their cage in an operant conditioning situation (about 70 pecks/days/4 hens) but they do not work intensively for space (about 20 times less than to obtain food) and the mean surface of the cage is extended only by about 600 cm^2 for a group of 4 hens if the normal cage surface is 400 cm^2 or 625 cm^2 per hen, i.e. to 550 and 775 cm^2 respectively. If the normal cage surface is 1125 cm^2 per hen they do not work any more (Faure and Lagadic, 1989). A decrease of the size of the reward has no influence on the work done (Faure, 1985). This holds true for hens kept in battery cages but animals reared in floor pens work a lot more (about 5 times more) to enlarge their cage in the same situation. However, this effect of floor rearing disappears in less than 6 weeks showing that habituation takes place quickly (Faure, 1990) but habituation to a cage does not remove the need to wing-flap (Bogner *et al.*, 1979: Nicol, 1987).

The preference for a large cage no longer holds true in the case of groups placed in a cage they could either enlarge or reduce. In these conditions out of 8 groups tested for 12 days, 2 always preferred the larger cage, 4 seemed to be indifferent to the cage size and 2 always preferred the small cage (Lagadic and Faure, 1990; Faure, 1994).

When placed in pens of 1410 cm^2/hen groups of 3 hens tend to space more than predicted (if distances were random) but tend to cluster if the pen size is 5630 cm^2/hen (Keeling and Duncan, 1989). This shows that their preferred inter individual distance can occur at pen size between these two values. However, operant conditioning gives contradictory results. Groups of 4 do not work to increase their cage size if the available surface is 1125 cm^2 per hen (Faure and Lagadic, 1989) it can thus be concluded that here, 1125 cm^2 per hen seems sufficient to satisfy the hen's preferences. The discrepancy between the two experiments might be due to strain differences but also to the fact that in Keeling and Duncan's experiment animals did not know each other before the start of the experiment whereas in Faure and Lagadic's the animals had been kept together for a long period of time. When the size of the cage is changed from 1040 to 2095 cm^2 for a group of 2 birds there is evidence that the larger cage provides more opportunities for the hens to perform some comfort behaviour such as head scratching, body shaking or feather raising (Nicol, 1987). Changes in frequency of some behaviour patterns appear when the surface per bird is reduced from 5630 to 600 cm^2 (Keeling, 1994a). Frequency of walking decreased between 3000 and 1200 cm^2, frequency of ground pecking decreased between 1200 and 600 cm^2. The frequency of standing increased between 3000 and 1200, probably as a time filler behaviour.

From these results it is very difficult to reach any firm conclusion as different methods give different results.

In physiological studies the effect of housing density on plasma corticosterone levels were measured (Craig and Craig, 1985; Koelkebeck and Cain, 1984 ; Mashaly *et al.*, 1984). Considering the conflicting results from these studies, they do not allow for definite conclusions on minimal or optimal space allowance (Craig *et al.*, 1986). All these physiological data deal with space requirements of hens kept in battery cages. No direct physiological data are available for hens on floor except on the decrease in productivity with increasing density and this is probably partly due to the problem of taking blood samples in floor pens.

Cage height has received much less attention than surface area. However, in one experiment Dawkins (1985) observed that nearly 25% of head movements occurred above 40 cm. In the same experiment hens given a choice between a standard cage with a height of 37 cm at the rear and 46 at the front and another with a variable height showed no preference if the variable cage was higher than the standard but avoided the experimental cage when it was lower. In a comparison of frequency of 20 behaviour patterns according to cage height, Nicol (1987) it was observed that the frequency of some of the behaviour patterns varied greatly between 30 and 42,5 cm but not, or at a lesser extent, between 42,5 and 50 cm. However, some behaviour patterns (Wing-flapping, tail-wagging) were shown to present a rebound effect when cage height was increased well over the 42.5 cm (Nicol, 1986)

The level and quality of activity, that depend on both surface and height of the cage influences bone strength (see chapter 3.2).

3.1.2 Group size and stability

In some of the experimental data available density and group size were confounded in the experimental design. Some of the results reported in this part could thus logically be in the previous one.

There are no results from either physiological or ethological studies which clearly indicate an optimal group size in laying hens. Choice experiments showed that the hen's preference for a specific group size depends on previous experience and the familiarity with the choice situation (Dawkins, 1982). On the basis of behavioural and physiological data, small groups are to be preferred in battery cages. Increasing the group size in battery cages usually has detrimental effects on most of the factors studied: egg production and fearfulness (Sefton, 1976), same characters and feathering (Craig and Miliken, 1989), frequency of aggression (Al-Rawi and Craig, 1975; Craig *et al.*, 1969; Zayan and Doyen, 1985), hysteria (Mills and Faure, 1990), feather pecking and cannibalism (Allen and Perry, 1975; Hughes, 1982; Zayan and Doyen, 1985) and mortality (Adams and Craig, 1985). Flickinger (1961) found heavier adrenals and thyroids in birds from groups of six than in birds from pairs, suggesting a stronger physiological stress response because of group size. It seems that in floor pens increasing group size from 13 to 70 birds enhances feather pecking and cannibalism

(Keeling, 1994b). Siegel (1985) showed the importance of social stability on stress responses, the introduction of foreigners in a group leading to an increase in stress.

Generally speaking all the papers dealing with the subject showed that increasing group size always creates problems.

Elmslie *et al.* (1966) tried to give a general theory on the effects of group size and density on productivity. From their data it seems that there is an important change when the group size is more than 4 birds. This result is also confirmed by Tind *et al.* (1984). Another threshold could be at about 100 animals as Guhl and Fischer (1969) suggested that this is the maximum number of conspecifics with which a hen can establish hierarchies, however, this is not supported by experimental data.

3.1.3 Laying nests

Nest building is relatively complex and involves making a depression in the material (if loose material is available) with the feet and breast, collecting material with the hen sitting on the nest, and sometimes gathering material (wood shavings, straw, feathers) away from the nest and transporting it on the hen's back (Wood-Gush, 1975).

In battery cages the sequence of behaviour patterns starts with the hen standing. This is followed by what looks like nest examination and is followed in some strains by sitting and vacuum nest building, and in other strains by stereotyped escape behaviour or pacing (e.g. Heil *et al.*, 1990; Meijsser and Hughes, 1989; Mills, 1983; Mills and Wood-Gush, 1985; Fölsch, 1981; Wood-Gush and Gilbert, 1969; Wood-Gush, 1972). Research by Duncan and Wood-Gush (1972) showed that stereotyped pacing also occurs during thwarting of feeding behaviour. They conclude that it is a sign of long-term and intense frustration and that there is evidence to show that this is aversive and leads to escape movements. Studies by Schenk *et al.* (1984), using specific sounds of the hens as an indicator of frustration, also suggest that birds without laying nests are frustrated during the pre-laying period. Recordings of heart rate during laying in hens with and without a laying nest (Kündig, 1977) showed a higher and more irregular frequency in hens without a laying nest. Plasma corticosteroid levels increase before egg-laying in hens with and without laying nests. In the latter, levels start to rise earlier before point of lay (Beuving, 1980). These data suggest that hens kept without laying nests have difficulties in coping with that situation. Inability to perform normal pre-laying behaviour is generally assessed as one of the most important problems for the welfare of hens in cages (FAWC, 1986).

The presence of loose material (wood shavings, straw) is an attractive factor in all the experiments (Kite, 1983; Huber *et al.*, 1985) but the important aspect seems to be the access to a mouldable or even to a pre-moulded nest (Duncan and Kite, 1989) rather than manipulation of the particles. Other aspects are important, such as the presence of an egg, social contacts, light intensity, confinement, height, competition (Kite, 1983; Appleby, 1984; Rietveld-Piepers, 1987; Lundberg and Keeling, 1996) but these seem to depend on the strain used or to interact with other environmental variables, in such a way that it is impossible to deduce general effects. As an example Sherwin (1993) showed that out of 12 hens in a MEC (with nest boxes), 1 consistently laid on the cage floor and 2 showed stereotyped pacing. This leads Petherick *et al.* (1993b) to conclude that "the variability of individual responses suggest that no single type of nest box system can cater for the requirement of all hens". However, in practical conditions, if pen and nests are well designed, and the flock well managed the proportion of eggs laid outside the nest is low.

3.1.4 Substrate

Floor structure can be considered as being of one of two fundamental types: particles (wood shaving, straw and sand); or mesh (wood, plastic, metal). In the first case they allow a wider range of behaviour to be performed normally (scratching, dust-bathing, nesting) but keep the animals in contact with manure. Mesh usually has a role in keeping the animals out of the manure (except in systems where part of the floor is slatted and part is litter) and is less suited for the performance of some behaviour patterns.

Hens strongly prefer litter floors to wire floors (Dawkins, 1981; 1982; Dawkins and Beardsley, 1986; Appleby *et al.*, 1988). It is also possible to show preferences for certain types of mesh to others (Hughes and Black, 1973) or to particles (Petherick and Duncan, 1989). The most obvious behaviours during which litter is used as a substrate are dust-bathing, nesting, pecking and scratching ("foraging"). Dust-bathing is strongly affected by the presence or not of litter, as by well as the litter quality, and the pattern is disturbed in battery cages (Rommers, *et al.*, 1991; Van Liere, 1991). Here, birds often use the feed as a substrate (Bessei and Klinger, 1982; Black and Hughes, 1974; Klinger, 1985; Martin, 1975; Vestergaard, 1981). It is surprising, however, that in jungle fowl the motor patterns of dust-bathing can also be performed in an almost normal way on wire mesh. However, birds housed on wire were less synchronized with other birds because it was difficult for them to start dust-bathing (Vestergaard *et al.*, 1990). After deprivation of dust-bathing hens show compensatory dust-bathing, indicating relevancy for the bird (Vestergaard, 1982). Dust-bathing regulates the amount of feather lipids and maintains down structure in good condition (Van Liere and Bokma, 1987). An artificial change in the quantity or quality of feather lipids was shown to influence the tendency to dustbathe (Van Liere *et al.*, 1989).

When litter is available it is intensively used by hens for scratching and pecking. In a "natural" or "semi-natural" environment, both jungle fowl hens and domestic hens spent a large part of their active time of day ground-pecking and scratching. Jungle fowl hens were observed ground-pecking in 60.6% of all minutes of observation (observations spread over the whole light period) (Dawkins, 1989), and the average percentage of time in which domestic hens were observed to peck and scratch was 47.9% (Savory *et al.*, 1978). In the simplified environment of a deep litter system, hens spent only about 9% of the time pecking and scratching in the litter (Blokhuis and Haije, 1986). In a situation without litter birds may redirect this pecking towards the feathers of conspecific (Blokhuis, 1986; Blokhuis and Arkes, 1984). Although the presence of litter is not guaranteed to prevent feather pecking, the data indicate the relevancy to the bird of ground pecking. For this reason, litter is an important element of the bird's environment. In an operant situation

(Lagadic and Faure, 1987) or in motivational conflict (Faure and Lagadic, 1994) hens show a high elasticity of demand for litter, implying that litter was not a high priority for hens. However, Matthews *et al.* (1993) found that bird would work for litter an showed an inelastic demand in another operant situation, implying that litter was a high priority for them. When given the choice between access to food or sand hens choose food even if sand deprived but not food deprived (Petherick *et al.*, 1993a).

Litter is thus a substrate preferred to wire mesh by laying hens and is necessary for the normal expression of some behaviour patterns, whether or not hens will work to obtain litter is sensitive to the methodology used, they do not accept an unpleasant stimulus to get access to litter, and chose food against litter even if not food deprived but litter deprived.

However, the quality of the litter should be considered. During summer when ventilation is not a problem, litter can easily be kept in good condition but during winter it can often be wet. In that case it is less suitable for the performance of dust-bathing, pecking, scratching, the plumage of the birds can get dirty and the pathological risks are increased (see chapter 3.2).

3.1.5 Light

In practice day length is usually between 14 to 16 hours in layers (gonadal stimulation). Good production results can also be achieved with intermittent photo periods (alternation of short periods of light and darkness).

The significance of light quality in relation to poultry welfare is still obscure. It has been suggested that natural light is necessary for laying hens (Huber and Fölsch, 1985a; 1985b). On the other hand a high light intensity may increase the risk of feather pecking and cannibalism (Hughes and Duncan, 1972). In white leghorns red light may reduce feather pecking (Schumaier *et al.*, 1968). In broilers, use of violet light may facilitate the capture of the birds before transport., Nuboer *et al.* (1993a), Nuboer (1993b) pointed out that there is a serious discrepancy between the chicken and human spectral sensitivity. Thus, the lux-meter is no longer the most appropriate instrument for most purposes in poultry research. Nevertheless, in studies on the effects of illumination levels illumination is usually measured in lux, which may in part explain the inconclusive effects reported in the literature.

Light intensity necessary to keep a normal laying rate is 5 to 7 lux (Sauveur, 1988) and light intensities well over 10 lux are usually avoided to decrease feather pecking. Intensity has no clear effect on behaviour except that there is evidence that hens are more fearful when kept in light intensities of 17 to 22 lux rather than at 55 to 80 lux and higher intensities increase activity and allow a wider range of behaviour (Manser, 1994). Another important aspect is that, at least in floor pens, light intensity has to be kept as constant as possible because spots of high light intensity are so attractive that hens might concentrate there and may pile up and some of them die (Hüber and Fölsch, 1985).

From operant choice experiments (Savory and Duncan, 1982) it appeared that hens preferred light to dark. Hens were also shown to "work" to get light but not to get dark. The results from this experiment are too limited for the evaluation of different lighting schemes. The effects of the intermittent lighting used in practice on bird welfare are not clear. In an experiment by Coenen *et al.* (1988) the Biomittent Lighting Programme was compared with a normal 14 h light - 10 h dark regime. It was concluded that circadian rhythmicity of the hens is maintained under both lighting schemes, although the BMLP-regime imposes more passive wakefulness during the day and slightly more activity during the night. Sleep during the night was slightly disturbed and this could be the result of some stress caused by the BMLP-day, as it is expected that behavioural patterns during the day are strongly affected by the BMLP regime.

Based on the behavioural responses, Tanaka and Hurnik (1991) concluded that a simulated dawn and dusk (gradual change in illumination) could be more comfortable for the birds.

Nuboer *et al.* (1992a) conclude that the direct light from fluorescent lamps driven by 50 Hz alternating current is seen by the chicken as flickering. However, hens do not appear to find fluorescent light aversive (Widowski *et al.*, 1992). Despite the fact that a low frequency flickering (100 Hz) is detected and has measurable behavioural effects (reduced activity) upon broilers (Boshouwers and Nicaise, 1992).

3.1.6 Perches

Perching has received very little attention despite the fact that in most floor-keeping systems of adult birds, perching is necessary to get access to nests and often food and water but perching behaviour is very often a resting activity. Unless otherwise stated the following results are from the study conducted by Faure and Jones (1982 a and b).

The type of perches usually available in poultry houses (length of wood) is not the preferred one when compared with a flat surface of wood or wire. In fact some strains never perch on a length of wood. This can depend on the photoperiod as all the observations cited were performed during the day but Blokhuis (1984) showed that in groups of jungle fowl and domestic medium hybrids all the birds perched during most of the night (except for some anticipation of sunrise) but only rarely perched during the day (10% of the perching is recorded during the day for the hybrids but only 1% in the jungle fowl).

The height of the perch is an important factor as a perch only 5 cm high is not considered as a perch and has no attractive nor repulsive value in floor pens. This questions the birds' motivation of the use of perches in battery cages (Tauson, 1984) and in this case the perch is probably perceived as a different quality of floor but not as a perch. These perches are however, readily used, the birds spending about 25% of the day time and 90% of the night time perched (Abrahamsson and Tauson, 1993; Appleby *et al.*, 1993). The use of perches caused deviation of the keel bone of some birds in the two experiments cited (see chapter 3.2). However, this problem was not encountered in some other studies.

During the lighting period the frequency of perching depend on the strain. Perching behaviour starts as early as 5 days of age (Hughes and Elson, 1977) in chickens and is well developed at 4 weeks of age. Some strains can start using a perch very quickly as adults but some other strains apparently never do so. Intra-strain variability is also very large and in most experiments some individuals never perched. In a detailed study of the development of perching behaviour Appleby and Duncan (1989) studied the perching behaviour of pullets given the opportunity to perch at different ages (from 4 to 20 weeks of age). They showed that birds having the opportunity to perch at 4 weeks of age showed a higher proportion of perchers than any other treatment up to 34 weeks of age. However, in the treatments with late access to perches the perchers showed the same amount of perching as animals with early access to perches after 4 to 6 weeks of access. There is no evidence of the occurrence of abnormal behaviour related to the absence of perches. A small amount of perching space can reduce aggression (Faure and Jones, 1982b) but the perches should not be too close to one another. They should not be too far either as it was demonstrated (Scott and Parker, 1994) that laying hens have difficulties moving between perches spaced more than one metre apart. At greater horizontal distances the risk of crash landing is increased. This has important implications for the design of non cage systems as risks of crashing also vary when the birds are moving up and down (Rauch, 1994).

One characteristic of perching behaviour is the lack of aggression. This allows, when only a small perching space is provided, very high densities on the perch. The maximum number of birds was 15 on a platform of 2116 cm^2 (Faure and Jones, 1982b), however, the perch length required if hens in a cage are to use a perch simultaneously is at least 12 cm (Tauson, 1984).

For perching behaviour a flat surface is preferred over a perch (Faure and Jones, 1982a) but in this case no discrimination is shown between wire and wooden surfaces. From a practical point of view a wooden surface is undesirable as it would become dirty very quickly.

3.1.7 Drinkers

Water consumption is constant or increases slightly during the morning in cockerels (Siegel and Guhl, 1956) whereas in laying hens the consumption is low before oviposition, increases sharply just after, is low during the second hour after oviposition and then increases slowly between 2 and 6 hours after oviposition (Mongin and Sauveur, 1974b).

In practice common available drinker space is 1 nipple or a cup drinker per 10 birds. Banks *et al.* (1979) observed no aggression at the drinker, even when access was limited.

There is not much physiological or behavioural evidence to show that drinking nipples disturb laying hens. Problems may occur, however, when birds are changed from open drinking water to nipple drinkers, if they are not properly prepared for such a change.

3.1.8 Feeders

In practice common available feeder space is 10 cm of feed trough or 4 cm of circular feeder per bird. (North, 1978). When taking into account the way animals space themselves, feeding space requirement is about twice as much as when considering only production factors (Faure and Mallard, 1973).

Aggression is frequent during feeding activity (Faure, 1977; Banks *et al.*, 1979). However, the importance of aggression has been largely over-estimated and social attraction under-estimated. Meunier-Salaün and Faure (1985) showed that hens with limited access to the feeder (5 x 5 cm hole per hen) tend to gather at the same access site (about 30% of the time when the distance between access holes is 40 cm). If a hen is forced to eat far from the pen mates the feeding time is reduced and the frequency of displacement activities (preening, pacing) is increased compared to the situation when she can eat in social conditions (Mills and Faure, 1989). This attraction seems to be important before, but not during, feeding, as different types of partitions (glass, wood) have no influence on bird's spacing (Mills and Faure, 1985). The use of partitions over the food trough results in a decrease in aggression but also in a decrease in feeding time and body weight (Preston and Mulder, 1989) and this was probably due to reduced social facilitation (Keeling and Hurnik, 1993) under these conditions.

When feeding space (in small groups) is too small to allow all birds to feed together, this has adverse effects on low ranked birds (Cunningham *et al.*, 1987). Experiments by Hughes and Black (1976) found that birds with 15 cm of feeding space showed a feeding pattern similar to that of hens in individual cages, but hens with 10 cm of feeding space did not. This suggests that a feeding space of 10 cm is not enough to allow undisturbed feeding in small groups. Even with 15 cm of feeding space, birds fed together in only 60 to 70% of all cases. The authors suggest that even 15 cm may be too limited. This interpretation is however, probably wrong as Meunier-Salaün (1983) showed that even with a one metre long food trough groups of 3 hens food deprived for 6 hours, the 3 hens were simultaneously present at the trough during only 56% of the feeding time. There is thus a statistical synchrony but it is unrealistic to expect it to be absolute.

Another important aspect of the feeding behaviour is that it is strongly associated with drinking. In battery cages the feeder is usually in front of the cage and the drinker at the rear and the length of the feeding bouts is short (less than one minute). This means that even if at one time a hen can not have access to the feeder it will have to wait for less than one minute to get access (Meunier-Salaün, 1983).

3.1.9 Genetics

Strain differences were observed for all the behaviour patterns studied and when selection was carried out it was always successful (Siegel and Dunnington, 1990; Craig, 1994). From this it can easily be deduced that strain reactions to different environments are different and this will have some impact on the welfare of the birds.

Some behaviour patterns closely related to welfare have already been subjected to experimental selection: pre-laying behaviour (Mills *et al.*, 1985); aggressivity (Guhl *et al.*, 1960); fear (Gallup, 1974b; Faure and Folmer, 1975; Faure, 1981a and b); frustration (Siegel *et al.*, 1978); feather pecking (Bessei, 1984; 1986; Kjaer, 1995); cannibalism (Craig and Muir, 1993).

A change in the frequency of some behaviours has obviously positive effects on welfare, e.g. a reduction in feather pecking tendency or in aggressivity. For other types of behaviour the link is not so obvious. Thus, a reduction of frustration behaviour or of pre-laying pacing may be due to a better adaptation of the bird to the environment or to another way of dealing with frustration (for example by physiological responses). It is up to the poultry breeders to include some of these factors in their selection indices. As far as it is possible to know this has not been done yet and seems unlikely in the near future as most of the competition between breeders is for growth or laying rate and also because quick measures of the behaviour are not available yet.

Another aspect is the "natural" or indirect selection occurring in parallel to breeding. The effect of this type of selection is to increase the adaptation of the animals to the environment in which they are selected and all the strains available are selected in battery cages. This should lead to an increase in the welfare status with generations if selection and production environments are similar but to a decrease if the two are different.

3.1.10 Rearing

Rearing conditions, and management during rearing, are shown to affect the behaviour of laying hens and their capacity to adapt to specific conditions in the laying period.

Hens reared without perches were shown to often have problems in perching, and this can have detrimental effects on the birds specifically when they are to be housed in an aviary type of house where they have to perch to get access to the nests (Faure and Jones, 1982b; Appleby *et al.*, 1983; Ehlhardt *et al.*, 1984) and to use the different platforms.

Measures such as the additional provision of grain during rearing have been shown to reduce feather pecking damage during lay, even when no additional grain was provided during lay (Blokhuis and van der Haar, 1992).
Access to litter during the rearing period has an important effect in reducing the amount of feather pecking in adults. This effect can be either through redirected ground pecking (Blokhuis, 1986) or abnormal dust-bathing (Vestergaard and Lisborg, 1993; Vestergaard *et al.*, 1993) in the birds deprived of litter during rearing.

The presence of litter can also act as an enrichment device as it was shown that enrichment can improve plumage cover (Jones, 1982; Church *et al.*, 1992). Enrichment can also decrease fear reactions (Reed *et al.*, 1993) and aggression (Gvaryahu *et al.*, 1994).

When laying hens are provided with nipple drinkers it is essential that they have been accustomed to nipple drinkers during rearing, otherwise deaths may occur due to the fact that birds are not able to use the drinkers.

3.1.11 Summary

Available space is a very important factor in hen housing systems. Despite a detailed review of scientific evidence, it is not possible to give figures for spatial requirements. The best estimate for a minimum space requirement, under specific conditions, is that which allows all normal movements for every bird but space sharing is important. Group size is also an important factor and it seems that an increase in group size brings a risk of cannibalism. The way that the space is used and any problems of aggression must also be taken into account.

A laying nest is very attractive for hens ready to lay and birds may show very disturbed behaviour if no nest is available.

Littered floors are strongly preferred to floors without litter. Litter is used in the performance of a lot of behaviour patterns (dust-bathing, nesting, pecking, scratching). In some experiments birds would not work hard for litter but in other experiments (in another operant situation) it was shown they did work for litter. When given the choice between access to food and sand hens choose food even if sand deprived but not food deprived. In larger groups than about 5 the absence of litter further increase the risk of cannibalism.

The quality of light does not appear as an important factor although hens prefer light to dark and brighter light to dimmer light. In dim light they are less active, show a smaller range of behaviour and they may be predisposed to show fear responses. Some intermittent lighting patterns seem to induce disturbances in the quality of sleep. High light intensities increase the risk of feather pecking and cannibalism.

Perches can be very attractive at least for some strains but there is no evidence of disturbance when no perches are available.

Food and water are very basic needs and the provision of sufficient access to both is very important.

Early experience, rearing conditions and selection can influence the ability of animals to adapt to different conditions, and hence their welfare.

3.2 Animal health

3.2.1 Introduction

The evaluation of animal welfare requires information on all aspects related to the health status of the animals under consideration. Although animal welfare is a question of the state of individual animals it is often, particularly in relation to egg laying hens, necessary to look into and draw conclusions from the herd or flock situation. This means that the evaluation of the impact of housing systems on animal health may often be expressed as disease percentages rather than as an effect on single animals.

Epidemic diseases, including a wide range of viral and bacterial diseases, are of great importance for modern methods of keeping hens. Successful vaccination programmes and management routines have reduced the risk of outbreaks of these diseases in modern egg production, which means that the disease spectrum has changed from a predominance of infectious diseases, which are largely independent of the system of production, to what are normally called production diseases.

Production diseases are characteristically multifactorial, which means that it is usually impossible to implicate a single factor as being the cause or agent of a certain disease. One or two factors may be the main causes of clinical outbreaks of production diseases, but other factors may be important too, and it is often a complex combination of several factors which eventually results in clinically observable disease.

Environmental stressors, which may be physical or social, thus have a direct impact on the health status of the animals. It is also important to recognize that stressors in general have an influence on the immunological capacity of animals. According to Moberg (1985) a stress response may result in suppression of the immune system, perhaps as a result of adrenal corticosteroid secretion, creating a risk to the animal from pathogens in its environment. The longer the stress response persists, the longer the period of vulnerability and the greater the likelihood of infection. It is in accordance with this general consideration of stress reaction and pathology that Gross and Colmano (1969; 1971), Gross (1972; 1976) and Gross and Siegel (1973; 1975) reported, that chickens selectively bred for a high level of plasma corticosterone or housed in an environment with a high level of aggressive social interaction are more resistant to bacterial and coccidial infections, more susceptible to viral infections and tumours, and produce a lower antibody response to antigen than those bred for a low level of plasma corticosterone or housed in an environment with a low level of aggressive social interaction.

When considering production diseases of hens in various housing systems it is important to point out that these diseases may be found in all systems. It is, however, characteristic for the prevalence of many of the diseases to differ from one system to another. A scientific evaluation of production diseases related to different housing systems may be founded either on planned epidemiological analyses including a sufficient number of flocks or on experiments, where a few housing systems may be compared under maximum control of the experimental conditions.

Unfortunately, both epidemiological analyses and controlled experimental investigations of production diseases are scarce. Among the comparative experimental investigations of diseases in different housing are those of Tauson and Jansson (1990), and Nørgaard-Nielsen (1986), Engström and Schaller (1993), Bosch and van Niekerk (1995) and Algers *et al.*, (1995). Surveys of autopsies and compilations of results from investigations in diagnostic laboratories are also available (e.g. Svedberg, 1986; Löliger, 1985), as are data on mortality rates in different systems (e.g. Miller and Quisenberry, 1959; Randall *et al.*, 1977). Although mortality rates per se do not reveal very much about problems in the different systems, they give some information on the general disease pressure in the respective systems.

In the following text a description is given of the most important production diseases of egg laying hens and of the housing factors most relevant to these multifactorial diseases.

3.2.2 Parasitic infestations

Egg laying hens in any production system may be infested with a wide range of external and internal parasites. The most important parasites of egg laying hens in Europe are a few external species, particularly the poultry red mite (*Dermanyssus gallinae*); intestinal Nematodes (roundworms), particularly *Ascaridia galli*; and intestinal Protozoa, particularly species within the genus *Eimeria* of *Coccidia*.

A parasitic infestation where the number of parasites is below a certain level and there is a balance between host and parasite will not normally create a health problem for the host. If, however, this balance changes and the parasites increase in number, the infestation may cause disease. Many factors affect this balance, particularly the host's general health status and immunological capacity. Environmental conditions also play a very important role. Thus, the general hygienic level in the poultry house, including possibilities for cleaning and disinfection, are very important factors in keeping the right balance between host and parasite.

The survival and reproduction of a parasite in a given egg production system are also influenced by environmental factors, including temperature, humidity and the construction of fittings.

The poultry red mite, for example, has better opportunities to reproduce and to infest hens in poultry houses rich in fittings such as roosts, than in laying cages where the mites may find it difficult to survive outside the host (Loomis, 1984; Maurer *et al.*, 1988; Höglund *et al.* 1995).

Intestinal parasites, including worms and coccidia, may survive, reproduce and possibly create disease problems when the hens are in close contact with their droppings e.g. in litter systems, particularly if droppings accumulate in wet conditions (Hilbrich, 1985;

Morgenstern, 1986; Braunius, 1989; Erhorn, 1987; Morgenstern and Lobsiger, 1993; Bosch and van Niekerk, 1995), and according to Bray and Lancaster (1992) the highest concentration of eggs from intestinal worms were found in the surroundings close to the houses in free range poultry systems.

3.2.3 Bone fragility

Bone fragility in egg laying hens is a well-known condition which is related to several causal factors including nutritional imbalance, the level of egg production and the birds' possibilities to locomote and thereby keep bones and muscles fit.

Skeletal weakness in hens was first reported as cage layer fatigue after the introduction of battery cages in the USA (Couch, 1955). The problem has been identified as a general loss of structural bone leading to weakening degeneration and fractures of bones. Wilson *et al.* (1992) confirmed that the bone loss is caused mainly by the progressive development of osteoporosis and Whitehead and Wilson (1992) describe how an apparent lack of new bone formation in reproductively active hens leads to a progressive loss of structural bone during the laying period.

Although lack of minerals in the feed of the high-yielding hen as well as the egg production per se may weaken in particular the leg and wing bones, it is generally accepted that restriction of movement is the main cause of bone fragility in egg laying hens (Simonsen and Vestergaard, 1978; Simonsen, 1983; Hughes and Appleby, 1989; Nørgaard-Nielsen, 1990; Knowles and Broom, 1990; Fleming *et al.*, 1994).

As bone fragility may lead to bone fractures the condition is very important in relation to the welfare of laying hens. Possibilities for the birds to move may differ widely in different environments and birds from traditional cage-housing systems are particularly at risk of breaking their wing bones while being caught and transported to the slaughterhouse (Simonsen and Vestergaard, 1978; Nielsen, 1980; Wokac, 1987; Gregory and Wilkins, 1989).

According to Gregory *et al.* (1993) the catching method during depopulation of battery systems had a significant effect on the prevalence of broken bones. Catching and removing hens by one leg from the cages resulted in 11 to 14 per cent of the birds acquiring a broken bone, whereas catching and removing each bird by two legs resulted in 5 per cent of the birds acquiring a broken bone. Removing more than one bird at a time from the cage tended to cause more skeletal damage than removing them individually, and incorporating a wood breast support slide over the feed trough had no effect on the prevalence of broken bones.

Fleming *et al.* (1994) concluded that battery caged hens had the poorest bones, as assessed by measurements of cancellous bone volume, radiographic density, cortical thickness and three-point breaking strength. It was also concluded from this investigation that the extent of movement allowed by different husbandry systems affects structural bone loss and bone strength in laying hens and that humerus structural and strength characteristics may be the best criteria of osteoporosis in hens.

It is, however, not only during catching and transport that fragile bones may break. Investigations of hens from different systems have also discovered old, healed fractures. Battery birds had a higher incidence of recently broken bones in comparison with perchery and free range birds. However, there were more old breaks in the perchery and free range systems than in the battery system. In battery hens these fractures were found mainly in the humerus, while in free range and perchery hens they were mainly in the furculum and keel (Gregory *et al.*, 1990). Introduction of perches in conventional cages caused inferior keel bone condition but increased the tibia strength in the hens (Abrahamson and Tauson, 1993). In contrast to this finding it was, however, demonstrated (Tauson and Abrahamsson, 1996) that keel bone lesions were only found in Get-away cages and not in conventional cages equipped with perches. In this study it was also demonstrated, that perches with a soft rubber cover did not reduce keel bone lesions as compared to perches made of plain European beech hardwood.

Bosch and van Niekerk (1995) from measurements of the bone strength found that aviary hens had stronger bones than caged layers. As a result fewer broken bones in the aviary bird were found due to depopulation of the hen house.

According to Gregory *et al.* (1991) the incidence of old breaks was greater in perchery birds than in tiered terrace birds and there was also a difference between two types of perchery design. The general construction of multi-tier and perchery systems, including flight distance between perches or tiers, may be important in relation to bone fractures in aviary-like systems. According to Scott and Parker (1994) there is an apparent threshold, at around 1.00 m, beyond which birds are less successful to negotiate between horizontal perches. Designs based on the birds' abilities to leap from one place to another are likely to improve bird welfare.

Gregory *et al.* (1991) also found that weak bones and broken bones at end-of-lay battery hens were more common in birds reared to point of lay on deep litter rather than in cages. This finding was unexpected and unexplained. Anderson and Adams (1994) found no rearing effect on tibia strength in battery hens reared in different densities in cages or floor pens until 18 wk of age. The tibia breaking strength was not different in hens maintained in cages with different floor mesh size.

According to the above quoted literature on bone fragility in laying hens especially battery hens may risk to break the wingbones at the end of lay during catching and transportation. Hens from aviary or perchery however may risk to break furculum and keel bones during the laying period. This kind of damages may be found at slaughter as old healed fractures.

3.2.4 Fatty liver Haemorrhagic syndrome (FLHS)

FLHS is a typical production disease mainly encountered in caged egglayers. According to Peckham (1984) the typical sign of the disease is a decrease in rate of lay. Birds appear healthy and in good physical condition. There is usually a 25-30% increase in body weight. Birds in excellent condition may die suddenly, without premonitory signs, from rupture of the liver. The capsule of the liver is torn, and large blood clots are present on the surface of the liver and in the body cavity. Large deposits of fat may line the abdomen and cover the intestines.

In a review of the literature on FLHS (Squires and Leeson, 1988) four factors are mentioned as responsible for FLHS. Among these factors environmental conditions such as high temperature, stress, and lack of exercise due to crowding may be important in relation to the housing of egg-layers in different systems. Simonsen and Vestergaard (1978) concluded that important factors related to FLHS were restricted locomotion, high environmental temperature and a high level of stress.

3.2.5 Foot disorders

Foot damage of different kinds is common in egg laying hens. Damage is seen in all systems, but its character may differ from one system to another.

The condition known as "bumblefoot" is a localized infection which causes bulbous swelling of the foot pad. Other types of damage include ulcerations under the toes and broken claws. "Balling" of the claws may be seen especially in hens in close contact with wet droppings and muddy earth where dirt may aggregate around the claw base.

Unfortunately, few investigations have been made into foot conditions in egg-layers and there are different opinions on the causes of the conditions recorded.

Svedberg (1986) recorded more foot damage in caged hens than in hens from litter house systems. Nørgaard-Nielsen (1986), however, recorded less foot damage in caged layers than in hens on litter floor and hens from the Hans Kier System. Simonsen *et al.* (1980) found equal frequencies of foot abscesses in hens on litter and on wire. In a comparative study including caged hens and hens from two alternative systems, both including a litter floor, Tauson and Jansson (1990) recorded bumblefoot only in the alternative systems. According to Siegwart (1991), perch construction and condition has a significant influence on the incidence of bumblefoot. Thus it was demonstrated that a 4.5 cm broad perch covered with 3-4 mm rubber eliminated the problem in that particular study.

According to Oester (1994) LSL hybrids developed no bumblefoot on wire perches, only few in the groups with channelled perches, double batten perches and perches covered by rubber and some more in groups with plastic perches. This study also included another hybrid hen (TETRA), and it was for this hybrid found, that it took some time longer till the first bumblefoot occurred, but then more birds were affected. It was suggested that the reason for bumblefoot was a non physiological pressure on the sole of the foot.

Tauson and Abrahamsson (1996) compared foot health in hens housed in get-away cages and conventional cages and it was found that bumblefoot lesions appeared only in Get-away cages while toe pad hyperkeratosis was found in the conventional cages only. Scores for bumblefoot were significantly different between different hybrids. In this study it was found that plastic was not a suitable material because it increased the incidence of bumblefoot, and that a soft rubber cover did not reduce bumblefoot compared with plain European beech hardwood perches of equal diameter.

It is a general opinion that hens in cages may have a uncontrolled and excessive growth of the claws, often leading to breakage of the claw with or without damage of underlying tissues. By fitting an abrasive strip on the baffle plate behind the food trough the front claws are effectively shortened. (Hill, 1975; Fickenwirth *et al.*, 1985; Nørgaard-Nielsen, 1986; Tauson, 1986).

3.2.6 Feather pecking

Feather pecking is a well known and potentially harmful behaviour which may be found in all housing systems. Feather pecking is a pecking activity involving the feathers only, and therefore the activity as such probably does not cause cognition of pain. It may, however, include feather pulling activity which may cause pain (Gentle and Hunter, 1990) and more importantly, it may predispose to cannibalistic pecking activities. Moreover, the feather pecking activity may eventually degrade the feather cover, which may interfere with the bird's body heat regulation and in crowded systems may give rise to skin damage caused by wear and tear from the environment and flock mates.

It is generally accepted that type of floor, density and flock size are important factors in relation to feather pecking (e.g. Duncan and Hughes, 1973 and Simonsen *et al.*, 1980). Light intensity in the environment may also be an important factor: avoidance of high light intensities may reduce the risk of feather pecking (Elson, 1990). Feed structure may also have an effect on pecking activity as Lonsdale *et al.* (1957) found with broiler chickens that feeding mash-crumbles-pellets as compared to mash increased feather pecking. Several authors have stated that feather pecks are redirected food- and ground pecks (e.g. Hoffmeyer, 1969 and Martin, 1986). Blokhuis (1986 and 1989) demonstrated that ground pecking and feather pecking increased simultaneously in groups of domestic hens on slats or wire floors and without access to sand, and Blokhuis and Van der Haar (1992) concluded, that the most important strategy to prevent feather pecking was to offer an adequate substrate, which should include the rearing period also.

According to Vestergaard (1989) another factor in feather pecking may be a misdirected dust-bathing pecking activity. Vestergaard *et al.* (1993) investigated relations of feather pecking and chronic fear in the red jungle fowl to dust-bathing, rearing environment and social status and it was concluded that the environment in which birds are reared may be significant for the development of feather pecking. The possible relation between feather pecking and dust-bathing was further investigated by Vestergaard and Lisborg (1993) and it was suggested that an association between dust-bathing and feather pecking might be prevented by formation of a strong association between dust-bathing and access to attractive stimuli like sand and peat as early as possible.

Nørgaard-Nielsen *et al.* (1993) investigated the effect of environment during rearing and laying period and it was concluded, that rearing with access to sand and peat for dust-bathing reduced the later tendency to feather peck, and that environmental enrichment in the laying environment by means of cut straw from a basket had a similar and additional effect. According to Hansen and Braastad (1994) rearing density had an effect on feather pecking. Low density birds had better plumage at 6 weeks of age and throughout the laying period. The low density birds ground pecked more frequently than high density birds during rearing and the laying period. At 12 weeks the low density birds feather pecked less than the high density birds, but no relationship was found between rearing density and feather pecking behaviour during the laying period.

Cuthbertson (1980) found genetic variation in feather-pecking behaviour and also according to Bessei (1984) there seems to be a genetical factor involved in the feather pecking activity of laying hens. The heritability however is of low magnitude. Keeling (1994) demonstrated that it is certain individuals do the pecking. Blokhuis and Beuving (1993) found higher feather pecking and object pecking in one of two genetic line of laying hens observed between 38 and 41 weeks of age. The higher feather pecking incidence in one of the lines resulted in more feather damage at 23, 30 and 42 weeks of age. Kjær (1995) found a genetic variation in pecking behaviour in 6-week-old chickens. The estimates of heritability were lower using pecks as compared with bouts of pecks.

3.2.7 Cannibalism

The term cannibalism describes the act or habit of eating parts of or entire conspecifics. In egg production, cannibalism is an activity which has been known for many years and which may be found in any system.

Cannibalism among egg layers is mainly seen in two forms. One is so-called cloacal pecking the other is severe pecking of the skin and underlying tissues. The term cannibalism is used because eating of blood and tissue may occur in both forms.

Cloacal pecking may start when the purple mucous membrane of the cloaca is exposed during the act of egg laying. This may stimulate flock mates to pecking activities, eventually leading to severe damage of the cloaca including perforation to the abdominal cavity followed by prolapse of the intestines and death of the victim (Wennrich, 1975). Cloacal pecking may occur without feather pecking and although both kinds of pecking activity may lead to cannibalism they should be considered as separate patterns.

The other and less severe form of cannibalism may start with pecking activities on feathers, including the pulling of feathers. In some cases this may cause minor bleeding, which stimulates further pecking of skin, connective tissues and muscles (Fölsch, 1977). This kind of cannibalism may not be fatal but damage to the victim may be so severe that it dies unless separated from the flock in time. According to Kuo and Craig (1991) and Craig and Muir (1993) selection for different traits of production had an influence on mortality rates due to cannibalism in White Leghorns. In this study it was also demonstrated, that as the amount of beak removal increased, beak-inflicted mortality decreased.

Mortality in egg-layers caused by cannibalism is found in cage systems (Randall *et al.*, 1977; Tind and Ambrosen, 1988) as well as in alternative systems to cages such as the covered strawyard system (Gibson *et al.*, 1988). Svedberg (1986) found in a survey of autopsies of hens from Swedish commercial laying flocks that cannibalism mortality rates were 10.3% for the caged birds and 9.4% for the litter-housed birds. Many factors predispose to cannibalistic pecking activities. Cannibalism may, however, be most severe where there is a combination of large flock size and high stocking density, perhaps because there are more target birds for "peckers" to attack. Its probability is increased by high light intensities which are unavoidable in some systems (Hughes, 1990).
Algers *et al.*(1995) recorded a 9% mortality in an investigation of the Oli Voletage system. One of the main reason for this figure was cloacal cannibalism and it was shown that cloacal pecking increased with increasing flocksize and increasing number of hens per nestbox.
Bosch and van Niekerk (1995) found in a comparison of beak trimmed hens in battery cages and a tiered wire floor system (TWF) a mortality of 5.6% in the cages and 6.4% in the TWF system. Approx. 9% and 20% of the mortality was caused by cannibalism in cages and TWF system respectively.

3.2.8 Beak trimming

The term beak trimming is commonly used to refer to the partial amputation of the beak. Beak trimming is common practice in the poultry industry aimed at preventing pecking damages of the birds (Craig and Lee, 1990; Kuo *et al.*, 1991). The operation usually consists of the removal of one-third to one-half of the upper mandible and often also about the same proportion of the lower one with a heated blade, which cuts and cauterizes the mandible. Routine beak trimming of day old chickens or chickens aged 1 to 8 weeks is performed in many hatcheries.

The purpose of beak trimming is to reduce pecking damages to the feathers and skin of the hens (Hughes, 1985). This means that in housing systems where the risk of feather pecking and cannibalism is evident the operation may be performed as a preventive measure (Gentle, 1986). Craig and Lee (1990) found that beak trimming was highly beneficial in reducing beak-inflicted feather loss and mortality from cannibalistic pecking in two of three commercial genetic stocks of caged hens. Poults of the third stock suffered no greater feather loss when their beaks were left intact than when they were trimmed, and mortality from cannibalistic pecking was essentially absent in this stock, regardless of beak trimming.

Although in certain genetic stocks the operation may reduce the risk of damaging pecking activities, it has adverse consequences for the birds. These include a reduction in feeding activity (Gentle *et al.*, 1982 and Duncan *et al.*, 1989) which leads to lower weight until the age of 35 weeks (Andrade and Carson, 1975). According to Craig and Lee (1990) body weight gain was initially suppressed following beak trimming but birds were only marginally lighter by 27 weeks of age. Birds may suffer persistent pain following the operation

(Breward and Gentle, 1985; Gentle *et al.*, 1990) due to the presence of neuromas. In contrast to these studies with older poults Gentle *et al.* (1995) found no evidence of neuroma formation after beak trimming of one day old turkey poults. Gentle and Hughes (1996) investigated behavioural and anatomical consequences of two beak trimming methods on 1 and 10 day old chicks. From this study it was concluded that mild or moderate beak trimming, where regeneration occurs, exerts its behavioural effects not by altering the length or shape of the beak but by sensory deprivation, removing the sensory receptors located at the tip of the mandible. These specialised receptors do not regenerate. The authors postulated that for effective trimming only sufficient beak to remove this specialized end-organ need be removed. However, since the study finished when the birds were 6 weeks old no information was gathered on the effect during the laying period. From other studies it is however known, that the effectivity of beak trimming in preventing feather damage depends on the proportion of the beak removed (Kuo and Craig, 1991; van Rooijen and van der Haar, 1990a) In the latter of these investigations the authors measured the amount of beak removed when the operator was asked to trim birds at 6 weeks old "short" or "less short". This resulted in 66.3% and 46.7% beak removed respectively.

Van Liere (1995) investigated the responsiveness to a novel preening stimulus after beak trimming in laying hens and concluded, that the operation had long lasting consequences in reducing the responsiveness to a novel preening stimulus. The finding that beak-trimmed hens are less responsive to a novel preening stimulus long after beak trimming, is in agreement with their long-term passivity as demonstrated by Lee and Craig (1991).

Grigor *et al.* (1995) investigated the effect of 3 different debeaking methods on turkey chicks. Of the different methods, trimming with a hot blade was not recommended. Electronic trimming appeared to offer the most benefits and caused little apparent distress, but can be hazardous in unskilled hands. Cold cutting may be the best compromise, but if too little of the beak was removed it could be less effective. In the long term, it was concluded, because beak trimming is a traumatic procedure, other methods of reducing damaging pecking must be sought. Gentle and Hughes (1996) suggested that if chicks are to be trimmed the procedure should be carried out at a young age (1 d and 10 d appear equally suitable) and that, provided cold cutting protects as well against subsequent pecking damage and cannibalism, then it may be preferable to hot cutting.

Van Rooijen and van der Haar (1990b) studied trimming with a hot blade at 6 weeks and they varied the temperature of the blade (850, 650 and 450 Celsius). They scored the beaks visually at the end of the rearing period and concluded that beaks trimmed at a lower temperature were more "normal" than beaks trimmed at a higher temperature. van der Haar and van Rooijen (1991) also compared hot blade trimming at 6 weeks with laser trimming at 1 day. They found some positive results with laser but the experimental set-up (age of trimming and methods of trimming were confounded) did not allow definitive conclusions.

Although beak trimming can reduce pecking damage it is preferable that hens should be housed and managed in such a way that beak trimming is not necessary. If beak trimming were to be disallowed it is likely that there would be an increase in the prevalence of feather pecking and cannibalism in some flocks. Practical experience indicates, however, that this can be controlled by reducing the intensity of lighting. With the present knowledge and experience such a reduction in light intensity is necessary with the present stock. Dimming the lights to ameliorate spasmodic outbreaks of these behaviours also results in poor welfare if normal activities are prevented. Some degree of light dimming is preferred to widespread prophylactic beak trimming, but it must be emphasised that it demands a high standard of stockmanship in recognising injuries to animals at an early stage.

3.2.9 Injuries

All housing systems for egg laying hens present a potential risk of different kind of injuries to the birds. Damage caused by cannibalism and bone fragility is described above. Other kinds of injuries include accidents where birds are trapped or injured by technical installations or mesh wire. These kinds of injuries to caged birds are described in detail by Tauson (1985). Commonly used battery cage equipment showed large differences in mortality rates due to trapping accidents including trapping of the head, neck, toes, claws, hocks and wings. Randall *et al.* (1977) also found in 2 of 51 caged laying flocks that accidents were a problem as birds in one flock became trapped by their hocks in floors, and in another by their feet and shanks at the front of cage partitions. According to Abrahamsson (1996) injury and mortality due to trapping is rare in well designed cages in good condition.

In free range and other "open" systems, birds may be exposed to low temperatures with the risk of frostbite of the comb and wattles (Elson, 1990). However, statistics about these injuries are not available. In free range systems losses may occur due to attacks by predatory bird or animals such as hawks and foxes. Löliger *et al.* (1982) reported that in 3 trials with free range Leghorn hybrids, losses due to predators were 3.8%, 10% and 21% respectively. These attacks may often, but certainly not always, result in quite a quick kill of the birds.

3.2.10 Diseases of the reproductive organs

Reproductive disorders are commonly diagnosed during autopsies of egg laying hens. These disorders include salpingitis, impaction of the oviduct and prolapse of the oviduct and cloaca, and are often followed by peritonitis and other abdominal changes. The disease complex is often related to the growth of coliform bacteria in the oviduct (Gross, 1984), and a high level of production with high oestrogenic activity seems to be associated with this bacterial growth. In a survey of mortality in 51 caged laying flocks Randall *et al.* (1977) diagnosed 15% reproductive disorders, which was only exceeded by the diagnosis of nephrosis/nephritis which accounted for 20% of the total mortality. Svedberg (1986) found from 22% to 32% of mortality was caused by reproductive disorders in Swedish autopsy material during the years 1974-1980.

Reproductive disorders do not seem to be related to any particular housing system. The high egg production may itself be a stressor which, in combination with a reduction in the immunological capacity due to a high level of oestrogenic hormones, may decrease the bird's general resistance to disease. Housing systems in which other stressors are present, e.g. crowding, social stress and lack of general stimulation, may further increase the risk of infection and clinical disease of the reproductive tract.

3.2.11 Effect of dust and ammonia on poultry health

DUST.

According to Koon *et al.* (1963) the bulk of the cage layer dust is flaky and cellular, consisting of skin debris interspersed with some food particles. Another common particle is broken feather barbules. In litter houses the dust also contains particles from the litter material and according to Grub *et al.* (1965) the dust production by layers on litter is a function of air moisture. This conclusion was supported by the finding that dust levels dropped as air moisture increased. According to Anderson *et al.* (1966) the dust content of air in a poultry house increases with an increase in the activity of the birds. In a comparison of floor types in broiler houses Madelin and Wathes (1989) found higher dust concentrations and numbers of airborne microorganisms in litter-floor houses than in those with netting floors. According to Hayter and Besch (1974) the largest dust particles (3.7 - 7 microns) were deposited primarily in the anterior portion of the respiratory system while the smaller particles (1.1 - 0.091 microns) were distributed equally throughout the rest of the system. Dust in a poultry house may serve as a pathogen disseminator and according to Wolfe *et al.* (1968) dust increased the number of turkey condemnations due to infections of the air sacs. Broilers on litter were also observed to have a higher incidence of lung damage than broilers on netting floors (Madelin and Wathes, 1989).

AMMONIA.

Concentrations of ammonium are generally higher in housing systems with manure compositing or open storage of slurry inside the house. Drost *et al.* (1995) found ammonia concentrations between 12.92 and 32.29 mg/m^3 in (semi) commercial aviary systems, see Chapter 3.4. Ammonia concentrations above approximately 25 ppm may have an adverse effect on the health and production of poultry. According to Marthedal (1980) young animals are more sensitive to ammonia than mature animals. The main clinical symptom caused by ammonia is kerato-conjunctivitis involving damage to the cornea and conjunctiva. In broiler chickens gross and microscopic lesions on air sacs were observed as early as 12 hours post-exposure in birds exposed to 100 ppm ammonia alone or in combination with either E. coli, dust or both (Oyetunde *et al.*, 1978). Ammonia damage in the early life of chickens may have a lasting adverse effect on laying hens. Charles and Payne (1966) found that White leghorn pullets exposed to ammonia levels as high as 78 ppm during the 11 to 18 week growing period showed an increase in the number of days taken to reach 50% production, and a reduction in hen-day egg production. According to Marthedal (1980) kerato-conjunctivitis may be seen in animals kept on litter as well as in animals kept on wire. This observation was confirmed by Madelin and Wathes (1989), who found no differences in the concentrations of gaseous ammonia between litter and netting floors in broiler houses.

The litter and manure handling methods as well as the temperature regulation of the house are probably of importance for the ammonia content in the air of the poultry house. Anderson *et al.* (1964) noted that when the litter moisture content rose above 25% and the house temperature was above 16 C ammonia was present in detectable levels.

3.2.12 Summary

Infectious epidemic diseases, including a wide range of viral and bacterial diseases, are largely independent of the system of production. This means that the animal health aspects of the welfare assessment may be concentrated on what are normally called production diseases. These diseases may be found in all types of production systems. Their prevalence usually differs from one system to another, due mainly to the fact that they are multifactorial: a combination of several factors including a stress-dependent reduction in immunological capacity eventually results in clinically observable disease.

Parasitic infestation, which sometimes leads to parasitic disease, may be seen in all systems of production but the least in cage systems. Difficulties in maintaining optimum hygienic and managemental conditions, and the accumulation of droppings in wet litter, may increase the risk of disease. This means that it is more difficult to control and prevent parasitic diseases in systems with litter and a lot of fittings than it is in battery cages.

Bone weakness and bone fractures of egg-layers may be seen in all systems. Bone weakness, which is an important factor as a cause of fractures, is predominantly seen in birds deprived of reasonable opportunities to locomote, i. e. those kept in battery cages. Fractures of weakened bones may be caused by rough handling of the birds as well as by accidents in systems where facilities for flying and landing are suboptimal.

Fatty liver haemorrhagic syndrome (FLHS) is a disease seen mainly in caged egg-layers. The disease may be seen in birds exposed to high environmental temperatures, lack of exercise, crowding and general stress.

Foot disorders of different types are seen in all systems. Little is known about their predisposing factors. It is generally considered that mechanical lesions, including broken claws, are seen mainly in birds housed in wire floor systems while inflammatory lesions are seen mainly in litter floor systems. Perch design presumably is an important factor in relation to the last kind of foot lesions.

Cannibalism may be found in all systems but the risk is lowest in small groups in cages. This damaging behaviour, may be most severe where there is a combination of large flock size and high stocking density. High light intensity is a predisposing factor.

Feather pecking, which may sometimes lead to cannibalism, may be seen in all production systems. It is, however, generally accepted that a wire floor, high density of birds, large flock size, a barren environment and a light intensity comparable to daylight are important predisposing factors. Feather pecking is, therefore, a problem in battery cage systems, particularly if the light intensity is above a certain minimum. Feather pecking is also a serious problem in many non-cage systems with a high bird density and large flock size, and where high light intensities are unavoidable. The three factors 1. early rearing method and environment, 2. environmental factors during the laying period and 3. bird genotype are very significant in relation to feather pecking.

Beak trimming is a mutilation with varying success in controlling feather pecking and cannibalism. The operation usually consists of the removal of one-third to one-half of the upper mandible and often also about the same proportion of the lower one. Different methods can be used including cutting with a hot or cold blade. Burning a small whole through the upper beak using a high voltage electrical current has been used in turkey chickens. The operation may have adverse consequences for the birds including acute and chronic pain, sensory deprivation, reduction in feeding activity and suppression in growth. Although beak trimming can reduce pecking damages it is preferable that hens should be housed and managed in such a way that beak trimming is not necessary. Until this can be accomplished the rather common use of the hot blade technique need to be reconsidered and replaced by a better technique.

Injuries may be seen in all production systems. Proper construction of the systems and suitable shelter and security for birds in "open" systems are key factors in minimising the risk of injuries to the birds.

Reproductive disorders are not related to any particular housing system. High production may itself be a stressor which, in combination with a reduction in immunological capacity due to high levels of oestrogenic hormones, may increase the risk of disease in the reproductive organs. Housing systems in which other stressors are present may further enhance the risk of infection and clinical disease.

Dust, on its own or in combination with micro-organisms, may cause disease of the respiratory system of poultry. Dust is present in all types of poultry house but lowest in battery cages. Problems may occur particularly when hygienic conditions are bad and there is a lack of control of ventilation, air humidity and litter quality.

Ammonia concentrations in the air of more than about 25 ppm may have an adverse effect on health and production of poultry. Ammonia above this level may be present in all production systems. The level of ammonia, however, is highly dependant of the way manure and litter is handled and may therefore be easier to control in some systems as compared to others. Manure handling systems and the handling and management of litter in litter house systems are probably of the greatest importance for the ammonia content in the air of the poultry house. Systems with litter containing a high content of wet droppings combined with a temperature above 16 C may in particular produce ammonia.

3.3 Productivity

3.3.1 Introduction

The use of productivity as an indicator of welfare in farm animals has been discussed extensively and controversially (Hill, 1983; Craig and Adams, 1984). According to Smidt (1983) and Adams and Craig (1985) the economic aspects of productivity should be separated from biological performance traits, and only the latter should be considered to be relevant to animal welfare. It seems to be generally accepted that adequate productivity of laying hens does not necessarily reflect good welfare, but low or a sudden drop in productivity may be an indicator of impaired welfare as it may be caused by stressors, such as high stocking density, low feeder space, diseases, etc. Comparative studies of cages and alternative systems, such as conventional deep litter, aviaries, free range systems, get-away or modified cages, have been carried out in various European countries (FAL, 1982; Kuit *et al.*, 1989; Sauveur, 1991; Blokhuis and Metz, 1992; Sanders, 1996).

3.3.2 Deep litter and free range systems

Early studies of egg production in cages versus floor systems have demonstrated the superiority in productivity of caged hens (Wegner, 1971; Scholtyssek *et al.*, 1983; 1984). Egg number, egg mass and feed conversion were better in cages as compared to deep litter. The differences, however, varied in magnitude and were not in all cases statistically significant. In a long-term study with a white and a brown hybrid strain in cages and on deep litter the egg number and egg mass per hen day was only slightly higher in cages. The differences in egg output in both strains were much higher when hen housed production was considered, because of higher mortality in the floor systems (Wegner *et al.*, 1981; 1983) (table 1).

Recent results from practical free range poultry farms showed that the hen housed production was about 30 eggs lower as compared with commercial cage systems (table 2). These figures cannot be directly compared because the duration of the laying period was 13 days longer and the mortality about 1,2 percent higher in the free range. Even if both traits are considered the overall egg number in the free range will still be considerably lower in the free range as compared to cages.

Feed conversion ratios are generally worse in deep litter systems. This is mainly due to low ambient temperatures during the cold seasons, and to extra energy requirement for locomotor activity.

The causes of lower egg production in deep litter systems are not clear. It cannot be excluded that the production as such may not be impaired by the housing system, and the difference may be due to the fact that floor eggs may be broken on the wire mesh of the manure pit or eaten by the birds, and therefore are not recorded. This assumption is supported by results achieved in some studies with free range and aviary systems.

Hughes and Dun (1986) reported similar egg numbers of a white and a brown layer strain (Shaver, Warren) in cages and in a deep litter system with access to free range. The egg mass was significantly higher in the free range birds, because of higher egg weight in this system. A similar tendency was found by Wegner *et al.* (1981). There is normally a negative correlation between egg size and egg shell beaking strength. In this case, however, egg shell strength in free range hens was higher despite higher egg weight. It was speculated, that higher light intensity, lower or fluctuating ambient temperatures in the free range may have stimulated feed intake, and thus, enhanced the development of egg weight. It is known that the intake of grass and leaves of free range hens increase the length of the digestive tract. This may improve the absorption of calcium and, thus, increase egg shell strength. Egg mass per hen day of a white and a brown layer strain was higher in the free range as compared to deep litter and cage systems, and egg shell strength in free range and deep litter were higher than in cages.

There was a problem with dirty eggs in most of the deep litter and free range systems (Wegner, 1983; Abrahamsson and Tauson, 1995; Nørgaard-Nielson *et al.*, 1993; Gerken, 1994) and the share of soiled eggs was often more than 10 percent of the total eggs. This percentage, however, is highly variable because it is influenced by nest type, nest position, floor type and a wide range of management factors.
Mortality rates in deep litter and free range systems are also highly variable. While the total mortality in caged layer flocks during a one years laying period is about 3-9%, it often exceeds 10 percent in deep litter and free range systems (Wegner, 1983).
The causes for high mortalities in deep litter and free range are mainly cannibalism, predators and ecto- and endoparasites (Löliger *et al.*, 1982).

3.3.3 Aviaries and Percheries

The main difference between aviaries and conventional floor rearing systems, which influences production traits is stocking density, and the position of perches, feeders and drinkers in several tiers. Reports on performance results in aviaries are available from Great Britain, Scandinavia, The Netherlands, Germany and Switzerland (Kuit *et al.*, 1989; Elson, 1991; Nørgaard-Nielsen *et al.*, 1993; Blokhuis and Metz, 1995; Gunnarsson *et al.*, 1995; Abrahamsson, 1996). The egg production records from commercial farms and experimental stations - were slightly lower in aviaries than in conventional cages (Keeling, 1989; Meierhans, 1992; Tanaka and Hurnik, 1992; Hansen, 1993; Nørgaard-Nielson *et al.*, 1993; Gerken, 1994; Grasenack and Tacke, 1994; Abrahamsson and Tauson, 1995). In some studies, however, there was no difference in egg output between aviaries and cages (Blokhuis and Metz, 1992; Niekerk and Ehlhardt, 1995; Horne, 1996) (table 2 and 3). As in the case of deep litter and free range any lower egg production rate may be the result of egg losses, which are caused by egg eating or total breakage, rather than depressed egg laying capacity in this housing system.

The problems of dirty eggs and high mortality are similar to those reported in conventional floor and free range systems. The main advantage of aviaries versus conventional deep litter systems is better feed conversion. High stocking density of 15 to 25 birds per sqm allows the temperature inside the poultry house to be maintained at 20-22 centigrades throughout the year. This is particularly important in poorly feathered hens. Wegner (1983) reported about high feed consumption of 140 g per hen day in deep litter and in a low-cost aviary, which was explained by extremely poor feathering of the birds and low temperatures. Recent evaluation of production results in various types of aviaries in the Netherlands have shown that there is virtually no difference in feed intake of hens kept in aviaries and in battery cages (Niekerk and Ehlhardt, 1995; Horne, 1996). Mortality was significantly better (6.7 versus 9.2%), and feed conversion was only slightly worse (2.27 versus 2.20 kg feed per kg egg mass) in the aviaries as compared with cages (see table 3). It was even noticed that the standard deviation of mortality, which is expected to be higher in alternative systems than in cages, was smaller in aviaries in this survey. The relatively good results of productivity in aviaries are explained by the fact that the hens in this study were severely beak-trimmed. Since cannibalism is a major cause for mortality in deep litter and aviary systems (Löliger *et al.*, 1982; Morgenstern and Lobsiger, 1993) beak trimming can currently be considered essential. There is scope to further improve the overall productivity in aviaries by improving the housing design, particularly nest boxes, and management.

3.3.4 Get-away and Modified Enriched Cages (MEC) cage systems

Though considerable efforts have been made to improve get-away cages since their first development by Bareham (1976) and Elson (1976), there are still considerable problems with this system (see Sherwin, 1994). There is a tendency for lower egg production as compared to conventional cages, though this difference it not always significant (Wegner, 1983; Rauch, 1994; Abrahamsson *et al.*, 1995) (see table 4). Egg eating was found to be one reason for lower "egg production" in the get-away cage in the study of Abrahamsson *et al.* (1995). Wegner (1991) reported lower egg production records in get-away cages with litter nests as compared with the same cages with roll-away nests. Increasing stocking densities by increased group sizes from 15 to 20 birds per cage and from 20 to 60 birds per cage did not result in significant reduction of egg production. In some cases mortality in get-away cages was higher as compared with conventional cages (Wegner, 1990; Abrahamsson *et al.*, 1995). Though the get-away cages were not worse than conventional cages in all production traits in the above cited experiments, there was a general tendency of poor performance in at least one characteristic (Wegner *et al.*, 1981; 1989; Rauch, 1994; Abrahamsson *et al.*, 1995). The causes of poor results in get-away cages are not totally clear so far. Larger group sizes may cause stress through increased social interactions (von Kleist, 1985). It should also be considered that poor hygiene in these cages may deteriorate productivity (Abrahamsson *et al.*, 1995). The availability of nest boxes and dust bath usually cause problems with egg eating, egg breakage and soiled eggs, and make regular control of the birds and the depopulation at the end of the laying period extremely difficult (Blokhuis and Metz, 1992).

The development of MECs seems to be more promising with regard to practical application. There was no difference in the egg output (laying rate, egg weight, egg mass) and feed conversion between modified enriched and conventional cages (Appleby *et al.*, 1993; Smith *et al.*, 1993; Abrahamsson *et al.*, 1995; Alvey *et al.*, 1995; 1996). Only problems with more dirty and cracked eggs in the enriched cages have been reported. These problems are being solved by ongoing research.

3.3.5 Genotype - System - Interactions

Since commercial hybrids have been selected under cage conditions for high egg production the productivity traits may be different under loose housing conditions. Genotype - housing - interactions have been reported by various authors. Fokina *et al.* (1980) and Lee and Craig (1981) found that chickens which had been selected in cages or on deep litter performed better in their environment of selection. In similar experiments Scholtyssek *et al.* (1983; 1984) selected White Leghorn lines for high egg production in cages and in deep litter compartments. The cage lines had lower production rates when tested in the deep litter system, but in contrast to the above mentioned experiments, the lines which had been selected in deep litter systems showed better performance when tested in cages. Wegner (1983) could not find significant line by system interactions in brown and white hybrids which have been tested under free range, deep litter and cage systems. Abrahamsson and Tauson (1995) compared the performance of two commercial hybrids under two different aviary systems. There were significant line by system interactions for egg production, feed conversion and percentage of cracked eggs. Abrahamsson *et al.* (1996) reported that two commercial layer hybrids showed different responses in feed conversion and mortality in cages and in aviaries.

This shows that genotype by system interactions for productivity traits have to be considered when new housing systems are being developed. Since the causal factors of the interactions are not known, it is not possible to predict the direction and magnitude of interactions. Therefore tests of alternative systems should comprise various distinct breeds.

3.3.6 Summary

The evaluation of studies on the productivity of laying hens in loose housing systems, such as free range, deep litter, aviaries/percheries, get-away cages and modified enriched cages have shown that the (biological) production capacity in these systems can be as high as in conventional cages. The recorded egg output, however, is often lower because a variable part of the laid eggs is lost by egg eating and breakage and therefore are not recorded. Feed conversion rates are generally worse in deep litter and free range systems. This is mainly caused by extra energy requirement for maintenance at low ambient temperatures. Poor feather cover caused by feather pecking increase heat loss and further deteriorate feed conversion. High stocking densities as usually practised in aviaries and percheries allows higher temperatures in the layer houses without supplementary heating and improves feed efficiency. Egg production systems with high stocking density require high management skill. Large group sizes which are common in alternatives to conventional cages increase the risk of cannibalism. Beak trimming is currently considered the only means to effectively control cannibalism in larger groups of hens. It also reduces damages caused by feather pecking and thus, positively influences feed conversion.

There is a tendency for increased egg weight and improved egg shell strength in the free range system. Mortality seems to be more variable in non-cage systems. Cannibalism, predators and parasitic diseases are important causes of mortality in these systems. Adequate floor material, controlled access to the nests and management procedures which reduce floor eggs can minimise the number of soiled and broken eggs. Dirty birds and impaired controllability are particular problems in get-away cages, which hamper their use in commercial egg production. Some of these problems may be solved in future by smaller enriched cages.

Since most commercial breeds have been selected for high performance in cages genotype by housing interactions have to be considered when the same breeds are kept under different environmental conditions.

Table 3.3.1. Summarized productivity traits of commercial layer hybrids (LSL) in free range, deep litter and battery cages for 3 laying periods of 52 weeks each (after Wegner *et al*, 1981)

Trait	Production system		
	Free Range	Deep Litter	Cages
Egg number per hen housed	266	267	279
Egg number per hen-day	291	286	287
Feed intake (g) per hen per day	134	132	123
Egg weight (g)	60,8	60,6	61,1
Egg mass (g) per hen per day	48,6	47,6	48,2
Mortality (%)	16	10	6
Dirty eggs (%)	9	12	2

Table 3.3.2. Results of a comparison between battery cages and free range systems in 1995 (Sanders, 1996)

	Cages	Free range
No. of flocks	140	22
No. of hens	2.917.000	80.255
Age at housing (days)	127,50	124,50
Age at replacement (days)	474	457
Duration of laying period (days)	341	328
Mortality (%)	5,20	6,37
Egg number hen housed	282	252,70
Egg weight (g)	61,20	61,46
Unsalable eggs (%)	6,00	6,33
Feed consumption per hen per egg (g)	112,90	129,12
Feed consumption per day (g)	133,10	165,00
Weight of spent hen (kg)	2,040	1,986
No. of hens per group	20.835	3.500
Whole sale price of eggs (FFr)	0,31	0,43
Costs of vet. treatment per bird (FFr)	0,20	1,50

Table 3.3.3. Productivity (means value and standard deviation) of White Leghorn Hybrids in aviaries and conventional battery cages (after van Horne, 1996)

Productivity Traits	Aviaries	Cages
Number of flocks	19	47
Duration of the laying period (days)	415 ± 26	410 ± 19
Eggs per hen housed	331 ± 17	325 ± 16
Egg weight (g)	61,0a ± 2,0	62,1b ± 1,3
Feed consumption (g per hen day)	114 ± 4,4	112 ± 4,1
Feed conversion (kg feed/kg egg mass)	2,27a ± 0,09	2,20b ± 0,08
Mortality (%)	6,7a ± 2,5	9,2b ± 3,6
Floor eggs (%)	4,6 ± 3,2	-

Means within a row with no common superscripts differ significantly ($p<0{,}05$).

Table 3.3.4. Productivity of White Leghorn Hybrids (LSL) in cages and Tiered Wire Floor (TWF) system as recorded in two production cycles from 20-26 weeks of age (after van Niekerk and Ehlhardt, 1995).

Productivity Trait	Cages	TWF
Egg production (%)	84,5 85,0	84,6 80,0
Egg weight (g)	62,2 60,1	60,7 60,6
Feed conversion (kg feed/kg egg mass)	2,20 2,20	2,27 2,53
Floor eggs (%)	- -	5,20 8,40
Mortality (%)	5,60 9,80	6,40 6,70

Table 3.3.5. Productivity of laying hens in Get-away cages (GA), Modified Enriched (ME) cages and Conventional cages (Co) in two experiments (after Abrahamsson *et al.*, 1995)

	Exp. 1			Exp. 2		
Productivity Traits	GA	ME	Co	GA	ME	Co
Laying (%) / hen day	81,6b	82,7a	83,5a	78,5b	82,3a	83,6a
Egg weight (g)	61,7	61,7	61,9	61,1	64,7	63,9
Egg mass (kg)/hen housed	19,4	19,9	20,4	20,2b	22,3a	21,9a
Egg mass (g)/hen day	50,0b	51,0a	51,7a	50,3b	53,2a	53,4a
Mortality (%)	13,3	7,8	8,0	8,6a	2,6b	5,8ab
Cracked eggs (%)	13,3a	5,7b	4,1c	18,6a	9,2b	5,0c
Dirty egg (%)	8,2a	4,1b	4,1b	4,9a	2,0b	6,0a
Feed consumption g/hen day	117,4	116,1	123,2	120,6	127,0	129,0

3.4 Egg Quality

3.4.1 Introduction

The consumer generally assumes that eggs from systems alternative to cages, and in particular those from free range, have better quality (better taste, healthier). There are various comparative studies on egg quality including battery cages, deep litter systems and free range, but it is unfortunately difficult to draw affirm conclusion. Not all of the studies have been designed in a way that direct comparison can be made because housing system is confounded with breed, age and feed quality. But even if the experiments were conducted with the same breeds, at the same age and with the same feed rations there are uncontrollable factors, especially in free range, which may influence the egg quality, e.g. the availability of feed of plant and animal origin (invertebrates) that vary with season and site (Savory, 1989). The results of various experiments from different countries (France, Germany, Italy, UK, USA, Yugoslavia, Poland, Tsechoslovakia, and India) have been reviewed by Sauveur (1991).

Since egg quality (e.g. shell strength, organoleptic quality, nutrient content, hygiene) may respond to changes in environmental conditions and housing systems, some traits may be used as indicators for the birds' welfare. Bain and Fraser (1993) and Fraser *et al.* (1995) considered the structural properties of the egg shell as potential indicators of the birds physiological harmony with its environment.

3.4.2 Egg weight

Though egg weight seems to be higher in cages as compared to floor systems in the major part of the reviewed experiments, there were studies which showed the opposite results. Taking the results of caged hens as a base line the magnitude of the deviation of deep litter systems varied from +4 to - 4 percent. In free range systems the variations were generally higher, and the reduction of egg weight in these systems compared to cages was more than 10 percent in some cases. The use of different breeds and feed rather than the keeping system may have caused these effects.

3.4.3 Egg shell quality

The effects of the housing system on egg shell strength do vary to a large extend, and particularly the resistance to fracture of eggs from free range deviate from cages in both directions (from +9 to - 7 percent). But there is an overall tendency of better eggshell strength in deep litter with or without free range. Cholocinska and Rozycka (1987) reported differences of 5 - 7 percent of cracked eggs on deep litter without free range versus 22 - 25 percent in cages. The better egg shell strength on deep litter and free range systems compared to cages may be caused by various factors. Lower ambient temperatures in deep litter and free range systems generally increases feed consumption and thus, calcium supply. It has also been speculated that the ingestion of litter and plants in these systems

increase the length and volume of the gut and thus, improve the absorption of minerals. The differences in egg shell strength among husbandry systems were more pronounced in the percentage of cracked eggs and characteristics of egg shell structure than in the conventional measures of egg shell strength, such as thickness and strength to fracture. This indicates that the lower egg shell quality in caged hens may be caused by defaults in the egg shell structure rather than in egg shell thickness.
An other particular effect of the housing system on shell strength has been reported by Hughes *et al.* (1985). Eggs shell strength in deep litter systems did not show a deterioration in response to the hens' age. This finding was not confirmed by Fraser *et al.* (1995), who found that eggshell quality as expressed in scores of structural variants, declined with increasing age in free range, deep litter and barn (perchery) systems. The eggs from hens in percheries had better shell quality scores than that from deep litter and free range in this study.
In a comparison of egg shell quality in conventional cages with and without perches Bain and Fraser (1993) found significantly higher incidence of defects in eggs from cages with perches in some ultrastructural shell characteristics. This has been explained as the result of stress, as not all hens could perch at the some time for insufficient perch space.

3.4.4 Colour of egg shell and egg yolk

Only a few results exist on the egg shell colour in response to the housing system. It is generally acknowledged that this trait mainly depends on genetic factors and may vary with age (coloured shells become usually lighter). But some experiments in which the egg shell colour of hens kept in different housing systems were compared, there was a tendency of darker colours in cage eggs (Pavlowski, 1987; Belyavin, 1988; Rauch, 1988). Extreme losses of colour in brown layer strains may be caused by diseases, and have been reported as a result of microbial infection of the oviduct in non-cage systems.
While the colour of the egg shell cannot be influenced by feed, the egg yolk pigmentation mainly depends on the type and level of carotinoids in the diet. Hens in free range eat variable amounts of grass and leafs containing carotinoids. However, the green fodder only effects egg yolk pigmentation when insufficient amounts of carotinoids are provided through the compound feed. In this case egg yolks of free range hens are darker than those from hens kept indoor (Pavlowski *et al.*, 1982; 1987; Belyavin, 1988).
Higher feed consumption due to the higher energy requirement of hens in free range is also expected to increase the carotinoid supply through the diet, and thus contribute to better pigmentation in this production system. In contrast to this there are experiments which showed a tendency of more intensive pigmentation of egg yolks in cages as compared to non-cage systems (Scholtyssek, 1975; FAL, 1982; Korenblik and van Niekerk, 1992). This may be explained by infections in the digestive tract which are found more frequently in non-cage systems, and which hamper absorption, transport and/or function of dietary carotinoids.

3.4.5 Albumen height, albumin index and Haugh Units

These traits are determined by the gel forming ability of the albumen and are generally used to appraise the freshness of the egg. The published reports reveal a high variation among production systems , and eggs from non-cage systems deviate from cages in both positive (Chand *et al.*, 1977; Pavlowski *et al.*, 1982) and negative direction (Scholtyssek, 1975). According to Torges *et al.* (1976) there was no significant difference in albumen height between cages and deep litter while eggs from free range had significantly lower values. In most cases the differences which were found among housing systems were not significant (Prasad *et al.*, 1981; Appleby *et al.*, 1988; Korenblik and Niekerk, 1992) and there is no explanation for those cases where significant differences haven been detected. It is assumed that the time the eggs remain in the nest or poultry house before collection rather than the effect of the housing system as such mainly cause changes in albumen quality.

3.4.6 Nutrient contents of the eggs

It has been demonstrated in many studies, that the nutrient contents of eggs, mainly of lipids and fat soluble substances, can largely by modified by the composition of the diet (Blanch and Grashorn, 1996). The housing systems in contrast, has little - if any - influence. Comparisons of cage and non-cage systems have been carried out by various authors (Scholtyssek and Woernle, 1967; Tolan, *et al.*, 1974; Torges *et al.*, 1976; Moore *et al.*, 1977; Scholtyssek, 1975; Majewska and Jankowsli, 1980; FAL, 1982; Mäkinen *et al.*, 1985). There was a tendency of reduced contents in some amino acids in non-cage systems with identical diets, which in some cases reached the level of significance (cystine, aspartic acid, glycine, methionine, lysine) (Scholtyssek, 1975; 1976). With the exception of the contents in cystine and lysine, which were higher in deep litter systems, Tolan *et al.* (1974) found results similar to the above studies for other amino acids, though the samples were taken from housing systems which differed with regard to breed, age and diet. Verwack *et al.* (1983) found significant differences in amino acid levels between eggs from small farms (free range) and industrial production (cages). In this case only lysine and arginine were lower in the non-cage systems, while other amino acids showed the opposite tendency. The magnitude of the differences among housing systems in all studies were rather small, and ranged from 0 to about 6 percent.

Differences in some lipids of eggs from cages and non-cages were shown for cholesterol and linoleic acid with higher levels in the non-cage systems (Bergami *et al.*, 1978; Tolan *et al.*, 1974; Scholtyssek, 1975; 1976; Torges *et al.*, 1976). There is a general tendency of lower lipid levels in the egg yolk with intensification of the production system (Ingre *et al.*, 1987), Since all cited studies have been published more than 10 years ago, more up-to-date information is required on potential differences between husbandry systems at similar egg production levels.

With regard to the vitamin level a study comparing free range, deep litter and cage systems with the same breeds and diets showed no significant differences or consistent trends (FAL, 1982). Lower levels in deep litter systems versus cages, which reached statistical significance in some cases, have been reported by Scholtyssek (1975; 1976) and Ristic and Freudenreich (1984). Significant differences between cages and non-cage systems (deep litter and free range) have been reported by Tolan *et al.* (1974) for folic acid and Vit. B12, with 40 respectively 50 percent higher levels in the non-cage systems. The Vit E contents was 20 percent higher in the deep litter systems but not in the free range. Since different diets were used in the different production systems, it cannot be excluded that this factor had a major influence. There was no difference in the mineral contents of eggs from cages and non-cage systems (FAL, 1982). Only Tolan *et al.* (1974) found lower levels of Ca and Fe in deep litter as compared to cages. In free range there was no difference for Fe but only for Ca. Here again the results are difficult to explain.

3.4.7 Yolk weight

Egg yolks from caged hens were slightly larger than that of hens on deep litter and in free range (Cholocinska and Rozycka, 1987; Scholtyssek, 1975; Pavlovski, 1987; Pavlovski *et al.*, 1982; Korenblik and Niekerk, 1992). The differences reached significance in some of these cases. In one experiment quoted by Pavlovski (1987) there was a non-significant tendency of higher egg yolk percentage in free range birds, and Cavalcini and Cerolini (1984) found equal shares of egg yolk in cages and deep litter systems.

Blood and meat spots (inclusions)

There was a high variation between cages and non-cage systems for the percentage of inclusions. Mench *et al.* (1986) reported 90 percent less inclusions in deep litter as compared to cages while Chand *et al.* (1977) found the opposite tendency of the same magnitude. Korenblik and Niekerk (1992) using white and brown layer strains could not find significant differences for blood and meat spots between cages and a Tiered Wire Floor System, though the brown strain showed significantly higher levels of meat spots.

3.4.8 Organoleptic traits

There was no difference in organoleptic characteristics of eggs tested either by trained panels or untrained consumers, whether tests were carried out with boiled or scrambled eggs, with whole eggs or yolk and albumin separately, provided the eggs were from hens fed the same diet (Scholtyssek, 1968; Torges *et al.*, 1976; Majewska, 1980; FAL, 1982; Haris and Gschwindt-Ensinger, 1982; Mäkinen *et al.*, 1987; Mench *et al.*, 1986). Eggs from all housing systems were found to be acceptable with regard to smell, flavour and texture. Differences were only found when eggs of hens from "real" farms (elevates "reellement" fermiers), e.g. from free ranging hens without controlled feeding were compared with eggs from industrial cage or deep litter systems, by a specially trained panel (Colas et Sauvageot, 1979). Though the test panel found differences between the groups, the real farm eggs as well as the industrial eggs met the expectation of the test panel, and among the real farm eggs there were groups with good and poor ranking. This clearly shows that there is virtually no basis to assume that eggs from cages are better or worse than those from non-cage systems. The organoleptic characteristics of hens from free range without controlled feeding systems may be distinct from industrially produced eggs, but they are not "superior" in all cases.

3.4.9 Hygienic aspects

The bacterial contamination of free range, deep litter and cage eggs has been studied by Torges *et al.* (1976). The total bacterial count was 420 x 10^3, 355 x 10^3 and 370 x 10^3 respectively. Approximately 45 percent of the eggs from deep litter systems were contaminated with Escherichia coli on the surface of the shell. The corresponding share in cages was 10 percent. E. coli inside the eggs (on the shell membrane) and on the yolk membrane were only detected in eggs from the free range. A later study of Matthes (1985) with eggs from the same systems confirmed the higher contamination with total bacteriae, E. coli, proteus and divers enterobacteria was lower in cages as compared to deep litter and free range. It was also shown in this study that the difference in bacterial counts among housing systems was small immediately after the eggs were laid, but the difference between the cages and non-cage systems increased significantly when the eggs remained more than 6 hours in the nests. This means that frequent egg collection and clean nests effectively reduce the differences in the hygienic status between cages and non-cage systems.

3.4.10 Summary

Comparative studies on egg quality under different housing systems showed a considerable amount of variation. In many cases however, there was no consistent trend. Taking conventional cages as a base line positive as well as negative deviations have been reported for most of the external and internal quality characteristics from hens in deep litter systems and free range. The variation was generally higher in free range than in deep litter. There is a tendency of higher egg shell strength, as measured by deformation and compression tests, in deep litter and free range as compared to cages. Some authors suggest, ultrastructural characteristics of the egg shell react to stressors. Hence they may be used as indicators of the level of stress in different housing systems. The colour of the egg shell mainly depends on genetic factors. Some experiments have reported darker colours in brown shell egg layers in cages as compared to non-cage systems. The egg yolk pigmentation is directly influenced by supply of carotinoids through the feed. Hence housing systems influence on egg yolk colour only in so far as they modify the supply or availability of carotinoids. Green forage in free range systems allow darker egg yolks when the level of pigments in the diet is sub-optimal. System-specific infections of the digestive tract impair absorption of the dietary carotinoids, and thus, produce lighter egg yolks. Differences in albumen quality (albumin hight, albumin index and Haugh Units) among housing systems were not significant in most of the reported studies. Small differences in the level of amino acids, lipids, minerals and vitamins have been found in eggs from cages and non-cage systems. Contradictory results have been found for the incidence of inclusions (blood and meat spots) in response to cage and non-cages systems. No significant difference has been found between cage and Tiered Wire Floor system. Organoleptic traits differed among production systems only when eggs from free range and uncontrolled feeding conditions were tested against eggs from industrial production, but eggs from free range were generally not superior to eggs from cages. The bacterial contamination of eggs in non-cage systems is generally higher than in cages. Frequent egg collection in these systems reduce the distance in the hygienic status of these systems to conventional cages.

3.5 Labour

3.5.1 Introduction

Apart from being a cost factor (see chapter 3.6), labour can also be seen as a production factor with limited availability, especially on family farms, where the number of hens that can be kept depends to a large extent on the available labour force. Several factors influence the number of hens that can be kept by one farmer, whereas other aspects of labour, like working postures, air quality and management tools, determine the quality of the labour.

3.5.2 Labour activities

The labour required for keeping hens can be divided into daily labour requirements, regular labour requirements and occasional labour requirements. Daily duties are by far the most important for determining the labour efficiency on egg production farms, since they make up 77-91% of total labour requirement (Hammer, 1983b).

Daily labour requirements include:

- Collecting eggs: this includes sorting out the second grade eggs, packing eggs and preparation for delivery. The amount of time spent on collecting eggs depends on the egg collecting system and the number of floor eggs.
- Inspecting hens: this includes the removal of dead, injured or diseased hens and, depending on the housing system, can be done together with other duties such as checking egg belts, collecting eggs and looking for floor eggs.
- Feeding: feed can be given by means of pans, troughs or hoppers. The amount of labour required depends on the system used and thus on the degree of automation.
- Watering: water can be provided by means of pans, cups or nipples. The amount of labour required depends on the system used.
- Checking nests: this involves closing and opening the nests. The amount of labour depends on the type of nest, as closing and opening can be automated.
- Checking feed and water system, this can be done during other (control) activities in the house.
- Management, including administration, consultation and health care: following developments in poultry husbandry, carrying out financial and technical administration and taking care of preventive and curative operations necessary for the health of poultry.

Regular labour requirements include:

- Manure removal: in many aviary and battery cage systems, manure is removed by belts or scrapers, from once every day to once every two weeks. In deep litter systems, manure is not frequently removed until the end of the production period.
- Cleaning: this includes sweeping aisles and cleaning nests, egg belts and watering and feeding equipment.

* Maintenance: this includes checking, oiling and adjusting mechanical equipment such as ventilation systems, motors etc.
* Repairs: this includes minor repairs during the production period.
* Litter management: in some housing systems litter has to be removed or extra litter has to be brought in.

Occasional labour requirements include:

* removing spent hens;
* removing litter at the end of the laying period in aviary and (deep) litter systems;
* cleaning and disinfection of hen-house and equipment;
* housing of new young hens.

Not all the work is always done by the regular labour force. Extra labour is needed in particular for removing spent hens and housing new hens, and removing manure and/or litter at the end of the laying period.

3.5.3 Factors influencing labour requirements quantitatively

The amount of labour required for keeping laying hens is not only determined by the number of birds, but also by the inspection procedure of the hens, the siting, number and lay-out of the hen-houses, the degree of mechanization and automation, flock size and stocking density and the housing system.

Inspection of hens

The inspection of hens can be divided into the inspection of the whole flock and the inspection of individual birds. Adequate inspection of the hens is thought to be essential for the welfare of the hens. For an adequate inspection sufficient light is necessary, but the place of the hens in the house may hamper this. E.g. the hens in the lowest tiers of a battery cage system cause a problem for inspection because the farmer has to bend, and for the fourth and upper tiers a special cat-walk is necessary. In aviaries and percheries hens can walk around whereas the presence of high tiers make inspection more difficult. Inspection of hens in large colony cages may also be difficult.

The proper inspection of all birds is a critical point, especially if larger flocks are housed in separate small units such as battery cages. For example, if it takes 2 seconds to inspect each bird and take any necessary action, it would take about 22 hours to inspect 40 000 birds. Sufficient time should be allocated to the inspection of hens, because this task is often underestimated in commercial circumstances. It is advised that the inspection of hens is therefore not combined with other tasks.

Siting, number and lay-out of the hen-houses

The amount of labour is related to the number of age groups, which usually corresponds to the number of hen-houses. Farmers who market their own eggs need an even egg production throughout the year and they will usually have two or more age groups. Labour requirements are thus spread evenly throughout the year. Table 3.5.1 shows an example of the effect of decreasing group sizes while the total number of hens are equal. A disadvantage of more groups is the greater total amount of work than it would be if all the birds were the same age (Hammer, 1983c). This effect is greater for birds in cages than for birds in deep litter systems.

Table 3.5.1. Relative changes in labour requirements caused by number of age groups (Hammer, 1983a).

number of hens/age group	6000	3000	2000
Housing system			
Deep Litter (%)	100	105	110
Cages (%)	100	122	138

The number of houses is determined not only by the number of age groups but also by the housing system. For instance 14.000 caged layers can be placed in one hen-house but for the same number of birds on deep litter one house would be too large, because the walking distances would be too great. In this case two or more houses would be needed (C.O.V.P., 1988).

Other factors affecting the amount of labour are the distance between hen-houses and their lay-out. As a rule of thumb, particularly for deep litter houses with more than 1000 hens per house, the wider the house, the greater the labour efficiency. But this is offset by the fact that in mechanized systems long and therefore narrow houses are more economical. With caged layers the effect of wider houses is not so evident and with aviary systems it is hard to establish a relationship since the space for the birds is always divided into sections of somewhat standard width, depending on the type of aviary. Differences in labour time, due to differences in width of the hen house can be attributed to differences in the aviary system, egg collecting system, number of aisles etc.

Degree of mechanization and automation

Large savings in labour requirements can be made by mechanization and automation. In the U.S.A., labour usage in caged layer farms in 1984 was only three percent of that required in 1941. This was mainly a result of the increased use of mechanization (Bell, 1985). Nowadays, differences in labour requirements due to the degree of mechanization and automation are mainly caused by differences in egg collecting systems, since feed and water systems are usually automated.

Egg collection

The collection of eggs is the main component of the total labour requirement, both in cage systems and alternatives to cage systems (table 3.5.2). For aviary systems the few surveys done come to the same percentage (Ehlhardt *et al.*, 1989b). In all cases the percentage will increase with increasing flock size, because the influence of other tasks (such as feeding, manure removal) will decrease.

Table 3.5.2. Some labour elements as percentage of total labour requirement in two types of housing (Hammer, 1983b).

	Deep litter	Cages
Egg gathering	60-78	62-65
Survey of birds	11-21	18
Feeding and watering	2-3	3
Sweeping aisles	0-1	2- 3
Removing manure	-	1- 5
Work between flocks	9-16	10

The amount of labour depends mainly on the system used for collecting eggs. Eggs from caged layers or from a system with roll-away nests are usually collected once a day, unless there is a lack of collecting space. In this case, eggs are collected twice a day, as is done in systems with litter nests. Collecting eggs twice a day instead of once results in cleaner and less damaged eggs but takes about 15% more time (Hammer, 1983a; Spalek, 1982).

Labour requirements also depend on the type of nest. In systems other than battery cages, the total egg collecting time depends not only on the egg collecting system, but also on the percentage of floor eggs and thus on the housing system. Using roll-away nests instead of litter nests halves the egg collecting time. Using an egg belt in combination with a collecting table or packing machine gives a saving in egg collection time of about 55% compared to egg collection from litter nests (Bosch, 1981). By using roll-away nests and egg belts, the collection of nest eggs can be as efficient as the collection of eggs by belts in houses with cages. The percentage of floor eggs in hen-houses with roll-away nests is usually higher than in systems with litter nests (Rietveld-Piepers, 1986), so more labour is required for collecting floor eggs. Litter nests are the most time-consuming as collecting eggs from the nests by hand and changing litter in the nests requires extra labour which is not fully compensated by the saving in labour due to fewer floor eggs.

Keeping hens in alternative systems to battery cages results in the possible presence of mislaid eggs in the litter on the floor or on tiers. A lot of research is being done to find a solution for this problem (Appleby, 1984; Rietveld-Piepers, 1987), but up to now the only result is a list of factors which influence the percentage of floor eggs, e.g. light intensity and distribution, rearing method and age of housing (Blokhuis and Metz, 1995). By taking these risk factors into account the percentage of floor eggs can be kept to a minimum. Regular collection of floor eggs at the beginning of the laying period requires a lot of labour, but will help to decrease the percentage of floor eggs. However, apart from these risk factors there also seems to be a random variation between flocks. This results in uncertainty in the amount of labour required for these systems.

In addition to the time needed for collecting eggs, time has to be spent on the egg collection system for checking, cleaning and maintenance. Collecting belts have to be checked frequently, cleaned, and the electrical and mechanical equipment has to be maintained. Labour can be saved by using an automatic system for removing hens from the nests at night.

Feeding system

Larger farms usually have fully automatic feeding systems which need very little labour. Smaller farms with battery cages may have hand driven feed hoppers which require some labour.

Watering system

Pans and some type of cups need regular cleaning. Nipple drinkers only need to be checked to see that they are working. This needs very little labour and can be combined with other inspection tasks.

Manure removal

In some systems manure is only removed at the end of the production period. If manure is removed during the production period, this can be done with scrapers or belts. Scrapers are sometimes hand-driven, which requires extra work.

Ventilation system

The ventilation of the animal house may be natural, in which case no fans are used and the air vents only need to be opened or closed. Mechanical ventilation systems with fans are likely to offer a better control of the inside climate, but have a much higher energy consumption. Both natural and mechanical ventilation systems can be controlled by hand, but become more and more fully automated in which case fans and inlet/outlet openings are controlled on basis of mainly temperature by means of a computer. The building structure, stocking density and ventilation system (capacity, control) should be appropriate for the local climate to prevent long term deviations from the optimum temperature for laying hens (21-24°C). It is well established that lower temperatures result in increased food consumption (about 1.5 g/d per hen; Emmans and Charles, 1977), while higher temperatures may decrease production results. The more sophisticated, well insulated controlled environment buildings containing intensive systems at higher stocking densities are generally therefore more economic to run. Good climatic control is essential for the welfare of the hen and the presence of an alarm system and an electricity backup are necessary in cases of emergency.

<u>Flock size and stocking density</u>

Flock size and stocking density are important factors bearing on the differences in labour requirement between different housing systems. Stocking density in itself has little influence on labour requirement, because the time consumption per 1000 hens is affected only for jobs with an "overhead" character such as inspection, survey and repairs (Hammer, 1983d). However, increasing density in any poultry house leads to increased flock size, and generally also increased automation, which does substantially reduce labour time per 1000 hens.

Flock sizes have increased up to about 10,000 - 15,000 hens in alternative systems to battery cages, while 50,000 hens per house are common for both cage and alternative systems.

Different housing systems have different stocking densities, which vary from 1 hen per 10 m^2 in free range systems to more than 30 hens per m^2 floor surface in houses with cages. For the purposes of marketing eggs, Commission Regulation (EEC) No. 1943/85 (E.C.) lays down maximum stocking densities in respect of farming systems for which the system is described on the pack.

Housing system

In terms of labour, the battery cage is the most efficient housing system for laying hens. Feeding and drinking equipment need little labour, hens can in general be inspected easily and the absence of floor eggs eliminates a time-consuming factor.

Percheries and aviaries approach the same degree of efficiency. On some points they succeed: feeding, drinking, manure removal and ventilation can be the same as in cages. However, the extra features added to improve the welfare of the hens cause extra labour (table 3.5.3).

Table 3.5.3. Daily labour requirement in minutes per day per 1000 hens, in a laying house with cages and TWF system (Ehlhardt and Hiskemuller; 1990).

	3-tiers	TWF aviary
Egg collection (with egg belts and one collecting	13.8	13.8
Collecting 2nd grade eggs + inspection	2.2	-
Floor egg collection + inspection (2% floor eggs)	-	4.4
Closing/opening nests	-	1.3
Feeding oats	-	0.7
Total labour requirement	16.0	20.2

The use of nest boxes means extra labour for checking and cleaning. The use of litter on the floor in most alternative systems to battery cages means extra labour for supplying it, keeping it in good condition and for removing it at the end of the production period. Also, the risk of misplaced eggs in alternative systems to battery cages, either in the litter or on tiers, leads usually to a higher amount of labour in these systems.

Finally, removing the hens at the end of the production period is often found to be strenuous and difficult work. Gregory *et al.* (1993) found an effect of the removing method of laying hens from battery cages on the prevalence of broken bones, whereas the ease of catching was influenced by the light intensities. Bosch and van Niekerk (1995) found less damages to the wings and legs of hens kept in the TWF aviary system after depopulation compared with hens kept in battery cages. The percentage of dead hens with broken legs or wings from the TWF system was also less. Both effects were attributed to the stronger bones of the hens in the TWF system.

Litter systems differ in the percentage of floor area covered by litter. This has implications for daily and periodic labour requirements. A greater litter surface usually results in more floor eggs which require extra labour to collect. A greater litter surface also requires more labour for supplying and removing litter (Anon., 1981). If the litter becomes too wet it needs to be worked over or extra litter needs to be supplied. Open water systems (bell, cup) are usually used, which means extra labour is needed for cleaning. At the end of the production period the lights are turned out and the hens are lifted off the perches.

Houses for free range are the same as either deep litter or aviaries and thus require the same amount of work as those systems. However, free range hens also have access to an outdoor area, which requires extra labour for checking hens and fences, pasture management, opening and closing pop-holes if not automated, etc.

3.5.4 Factors influencing labour qualitatively

The effect of farm and labour organization, management, labour hygiene, working conditions and professional skill have mainly an effect on the quality of the labour, although they may also affect the labour requirements quantitatively to some extend.

Farm and labour organisation

Farm organisation
In addition to the factors already mentioned, the overall structure of the farm must be taken into account. A farmer may have more than just laying hens on his farm and may have to divide his labour between different tasks. As long as there are not too many tasks which need to be done at the same time, he will manage. In this situation caged layers are the easiest to handle, because eggs can be collected at any time. In systems with (deep) litter it is necessary to collect floor eggs at set times.

Labour organisation
Labour organisation depends largely on the housing system. In a fully automated battery cage house labour will start with checking feeding and watering systems, inspecting the birds and removing dead or diseased hens. Eggs can be collected at any time of the day as the lighting period in battery systems is artificially controlled. Daylight is sometimes provided in deep litter systems, but has severe disadvantages, because the farmer needs to arrange his working hours accordingly the natural daylight period.

Deep litter systems require the regular collection of floor eggs, especially during the morning hours. This means getting up early and it allows the farmer little time for other duties during the early morning. This can be changed to some extent by changing the starting time of the artificial day for the hens.

Management

Lokhorst (1996a) carried out research into the daily management support in aviary systems, which concentrated on taking adequate and timely decisions with respect to the production process in the hen-house. One important difference between aviary systems and battery cage systems is the fact that the birds run loose in aviary systems. Therefore, the collection of information on a certain place in the hen-house cannot be linked to a fixed number of birds, which restricts the setting up of automatic data recording, e.g. weighing. Attention was paid to the measurement of the number of eggs and egg weight per laying nest and the automation of bird weighing. The eggs that were laid were not equally distributed over the laying nests. It was concluded that in aviary systems eggs must be counted per unit or fenced off compartment (Lokhorst and Vos, 1994; Lokhorst and Keen, 1995). In order to get the correct weight of the birds from an automatic bird weighing system, the position of the scales is very important. The scales can best be placed on a feeding tier.

For the support of every day decisions concerning production, a prototype of an expert system was developed, which was linked to a commercial management information system (Lokhorst and Lamaker, 1996). This expert system is based on three critical success factors, daily information about feed consumption, control of house temperature and early detection of diseases, and gives the poultry farmer the chance to use the daily input for analyses purposes and to be able to trace aberrations in the production at an early stage. In the system, a descriptive model of the production had been included (Lokhorst, 1996). The use of a decision support system can reduce the economic risks of aberrations in the production process.

Labour hygiene

Internal environmental effects are related to labour hygiene for the stockman and the air quality of the living environment of the hens. The latter is described in chapter 3.2.11. Aspects of labour hygiene are related to:

1. ammonia concentrations and other gases like carbondioxide
2. dust concentrations and concentrations of endotoxin herein
3. concentrations of bacteria, fungi an probably other (pathogenic) microorganisms
4. climatic parameters: temperature, humidity, air velocities

High concentrations of dust, ammonia, carbon dioxide, fungi and bacteria can influence the health of workers in the hen-houses. Inhaling organic dust can lead to disturbances in the bronchial tubes. After long term exposure a stricture of the bronchi and even a decrease of the total lung capacity can occur. Exposure to ammonia has an irritating effect on the bronchi, the eyes and the skin. High concentrations of carbon dioxide can lead to tightness of the chest and can result in deeper and more difficult breathing. Almost nothing is known about the effects of fungi and bacteria in the air of hen-houses to the health. It is probably that bacteria influences the bronchial tubes. The Dutch labour inspectorate established some standard for a number of components that are mentioned (Labour inspectorate, 1992), the so called MAC values. However, it may be better to make comparisons with maximum exposure values that are based on research in the agricultural area: maximum exposure values. Chronical effects of the mentioned components can only be determined after being exposed for years. However, short term effects can be used as an indicator for possible health problems after a long time. It should be noted that neither the MAC values, nor the maximum exposure levels (can) safeguard the stockman against health effects. Table 3.5.4. to 3.5.6 summarize the results of a research into aviaries, other loose housing systems and battery houses in The Netherlands, Sweden and Northern Europe.

Table 3.5.4. Mean concentrations of aerial components in various housing systems for laying hens on commercial farms. Maximum exposure levels mentioned by Donham (1987) and MAC-values are also given (Drost *et al.*, 1995).

Component	semi-comm. TWF aviary	comm TWF aviary	comm TWF aviary	commercial Multifloor	semi-comm. battery cages	MAC-values	Levels by Donham
Total dust (mg/m^3) *)	16.92	8.76	12.64	7.56	1.93	10	2.4
Respirable dust (mg/m^3)	7.56	4.07	5.57	3.69	0.48	5	0.23
Inspirable dust (mg/m^3)	16.37	9.01	-	-	3.87	-	-
Fungi (cfu/m^3) *)	$7.5 \cdot 10^3$	$1.8 \cdot 10^4$	$7.5 \cdot 10^4$	$3.1 \cdot 10^5$	$2.7 \cdot 10^3$	-	$6.3 \cdot 10^5$
Bacteria (cfu/m^3) **)	$1.0 \cdot 10^6$	$2.8 \cdot 10^5$	$9.1 \cdot 10^4$	$1.7 \cdot 10^4$	$5.6 \cdot 10^4$	-	$1.3 \cdot 10^4$
Endotoxin (ng/m^3) *)	367	361	-	-	19	-	80
Ammonia (mg/m^3) **)	12.92	32.29	23.02	1.82	3.16	18	-
Carbon dioxide (mg/m^3)	1649	3057	2491	2029	1681	9000	2836

* significant difference between the battery cage system and all aviary systems.
** significant difference between the TWF aviary systems and the battery cage and Multifloor system.

Table 3.5.5. Concentrations (ppm) of ammonia and carbon dioxide in two houses for laying hens (Mårtensson, 1995).

	Ammonia		Carbon dioxide	
	mean	range	mean	range
battery cage with manure belts	2	1-3	2700	2200-
loose housing systems with litter and	33	25-40	1900	1400-

Table 3.5.6. Mean and maximum concentrations of ammonia (ppm) for two housing systems for laying hens in the United Kingdom, The Netherlands, Denmark and Germany (Groot Koerkamp *et al.*, 1996).

Housing system	U. Kingdom		Netherlands		Denmark		Germany	
	mean	max.	mean	max.	mean	max.	mean	max.
Deep litter / perchery	8.3	63.9	29.6	72.9	25.2	72.3	-	
Battery cages	11.9	67.1	5.9	16.5	6.1	14.5	1.6	21.4

Ammonia concentrations

Concentrations of ammonia are generally higher in housing systems with higher emissions of ammonia, e.g. systems with manure composting, open storage of slurry and litter in the house. Drost *et al.* (table 3.5.4) found ammonia concentrations between 12.92 and 32.29 mg/m^3 in (semi) commercial aviary systems, with one exception of 1.8 mg/m^3 due to the exceptional manure handling and litter condition, compared to 3.16 in a battery house. The levels in the aviaries were higher than the MAC value, which is 18 mg/m^3 or 25 ppm. Mårtensson (Sweden) and Groot Koerkamp *et al.* (Northern Europe) also found much higher ammonia concentrations in housing systems for laying hens with litter (Sweden, Netherlands, Denmark) or long term manure storage (UK both perchery and battery cage) (table 3.5.5 and 3.5.6). The ammonia levels often exceeded the MAC-values.

In deep-pit houses or other systems with open and long term manure storage in the hen-house, the presence of ammonia and flies can make working conditions very bad. This was also found by Mårtensson (1995) for rearing systems for laying hens and concentrations were higher during the winter than during the summer time. He concluded that regular removal of manure by endless manure belts is necessary to achieve acceptable levels of ammonia.

Possibilities to reduce emissions of ammonia, and hence ammonia concentrations, are described in chapter 3.6.

Dust concentrations

The dust concentrations in the aviary houses were 2.5 to 15 times higher than in the battery houses (table 3.5.4). The contribution of respiratory dust in total dust (fine dust) in the aviaries was about 46%, while about 27% was found in a battery house. The composition, and thus the harmful effect of dust can be different for different housing systems. Dust concentrations in aviaries were lower in the morning (5.88 mg/m^3) than in the afternoon (12.22 mg/m^3), which is probably due to the dust-bathing of the hens during the afternoon (Drost *et al.*, 1995). The concentrations of dust during manure removal were more than twice as high than during other activities of the stockman in the house (control, gathering floor eggs). According to Anderson *et al.* (1966) the dust content of air in a poultry house increases with the activity of the birds. Mårtensson found higher concentrations of total and respirable dust in loose housing systems (2.6-4.1 and 0.08-1.13 mg/m^3 respectively for rearing hens compared to cage rearing (1.3-2.7 and 0.07-1.04 mg/m^3). The higher activity of free range hens in litter can cause high concentrations of dust.

Higher outside temperatures lead to higher ventilation rates and this caused lower dust concentrations. Removal of litter reduced the dust concentrations by 24% in an aviary. However, concentrations were still high. It was concluded that manure, flakes of skin, feathers and feed contribute to the dust in the air, however, the relative contribution could not be quantified. The labour conditions in aviary systems should be improved because exposure to the measured dust levels increased the body temperature of man and increased the number of complaints (Drost *et al.*, 1995).

The production of dust and the dust levels depend on the moisture concentration of the air (Grub *et al.*, 1965). Madelin and Wathes (1989) found higher dust concentrations and numbers of airborne microorganisms in litter-floor houses than in those with netting wire floors.

The time spent in the hen-house depends to some extent on the rate of mechanization and the housing system. For instance, with an aviary the farmer spends approximately 6 times longer in the hen-house than with a caged layer house (Ehlhardt *et al.*, 1989). This means he is exposed to dust and ammonia 6 times longer. Because dust levels are usually higher it is necessary to wear a protecting mask or helmet, which makes labour more strenuous. In deep litter and caged layer houses it is also advisable to wear such protection, but because the level of dust in these houses is usually lower, farmers do usually not feel the need to wear protection.

Microorganisms and endotoxin concentrations

The concentrations of bacteria, fungi and endotoxins were in general higher in the aviaries than in the battery cage system (table 3.5.4). Mårtensson found higher levels of airborne microorganisms and endotoxin concentrations in the dust in the air in alternative rearing systems compared to cage rearing systems. This was explained by the presence of litter and sometimes long term storage of manure in the loose house and multiple tier rearing system.

Climatic differences

High environmental temperatures cause birds to eat less (heat stress) than when they loose much heat to the environment (cold stress). The economically optimal temperatures are between 20 and 22°C for a fully feathered bird. In hot and cold climates, houses should therefore be adequately insulated so that birds can be kept producing at the lowest possible Feed Conversion Ratio (FCR = Units of Feed : Units of Produce).

In principle, both with mechanical and natural ventilation systems the internal climate can be controlled. Commercial farms tend to favour mechanical ventilation systems because of the more advanced control systems and possibilities for higher ventilation rates in case of high temperatures. However, also with new advanced natural ventilation systems good climatic control can be achieved, but these are rarely used.

The stocking density (number of hens/m^2 floor area) determines the heat production and thus the required minimum and maximum ventilation rate in extreme outside weather conditions. Especially in alternative systems to battery cages with stocking densities below about 18 hen/m^2 it is hard to maintain the optimal temperature of 20°C in case of cold weather.

A comparison between a TWF and a battery cage system revealed the following (Lokhorst *et al.*, 1995):

- temperature variations in time and space are larger in aviaries due to movement of the hens,
- aviaries require a somewhat higher ventilation rate per hen due to the higher activity of the hens which leads to higher heat production,
- a more advanced temperature control (e.g. more temperature sensors) in aviaries is required because of the movement of the hens during the day,
- heat stress in summer conditions can be less because hens can stay in the coolest places (mostly the upper tiers).

Other research indicates that different housing systems cause differences in air quality (Drost, 1990; Bijleveld 1990; Hauser, 1990). The presence of litter means higher dust levels and therefore a more aggravating environment to work in. Houses with natural ventilation seem to have higher levels of dust and micro-organisms in the air (Hauser, 1990). Results of an EU-project on aerial pollutants in animal houses in the United Kingdom, The Netherlands, Germany and Denmark also show that air quality in poultry houses can be very bad for human and may cause a severe risk on the health of the workers in these system in the long run.

Working conditions

Working conditions are not only influenced by the quality of the air and the presence or absence of vermin, but also by the housing system itself. The farmer can walk through the aisles, check feeding systems and take hens out of the cages easily in case of well designed cages. To inspect the lowest level properly it is necessary to bend down. With more than 3 levels of cages above each other, special equipment such as a catwalk or bicycle is needed to inspect the upper levels. In small farms, hand-driven feed hoppers can make labour more strenuous. At the end of the production period, the spent hens can be removed in full light.

In fully open deep litter houses farmers need to walk through the litter and over the wire floors without injuring the hens. This is less comfortable than walking through a concrete aisle. Collecting floor eggs puts a heavy burden on the farmer's back.

Aviary and perchery systems have labour requirements additional to those mentioned for deep litter systems. In several aviaries the wire floors are placed against a wall and the lowest wire floor is approximately 30 cm above the litter floor. In these situations it is difficult to inspect the lowest level, especially if brown hens are used. In systems with three or more tiers, it is difficult to check the upper wire floor without climbing on the first wire floor. This climbing has to be done at least once a day, which makes these systems less suitable for older farmers. Finally, spent hens have to be removed in the dark, which is an aggravating factor for labour. Lundqvist (1992) pointed also to the more risky environment and the poor working postures of farmers in loose housing systems for laying hens. He gave several options to improve the working environment of the farmers, but extra costs are of course involved.

Top *et al.* (1995) carried out an ergonomic problem analysis on three commercial aviary farms and five battery farms in The Netherlands. On aviary farms 79% of the working time was spent on direct production tasks, namely the sorting and packing of eggs (42%) and the gathering of floor eggs (37%). The reduction of the number of floor eggs and the prevention that eggs are laid on places that are hard to be reached (especially the litter), will contribute very much to decreasing the labour need and eliminating damaging working postures in the aviary system. It turned out that the use of innovations like a trolley, a pick up stick and a litter removal machine are labour-saving and labour relieving. The necessity for a litter removal machine seems to be outdated by modifications in the design of aviaries. The use of a egg collector on the tiers, possibly covered and equipped with conveyor belts, makes the gathering of these floor eggs easier and can possibly lead to a more flexible distribution of the work over the day. Technical and organizational measures such as increasing the buffer capacity of the egg conveyors and pre-selection of floor eggs, seem to further reduce the labour requirements on aviary farms.

Despite being a study of only a small number of farms in The Netherlands, the labour research of Top *et al.* (1995) shed light on a very serious bottle-neck in the aviary house, related to working postures during the gathering of floor eggs and the checking of the hens. Modifications, such as lowering the lowest tiers and making the tiers sloped, considerably shortened the time that was needed and will decrease the number of damaging working postures. The illumination level in the house usually did not meet the standards in both the aviary or the battery houses. It was recommended to raise the illumination level temporary while operations are performed in the hen-house. Concerning the packing of eggs, the same bottle-necks were found in both housing systems. These problems concerned lift demands, illumination, working height and width, foot/leg space. Reorganization of the working spot, together with optimal mechanization aids form possible solutions to this bottle-neck.

An oral questionnaire held on 12 aviary farms and 12 battery cage farms showed two clear differences between aviary and battery farms (Top *et al.*, 1995). The working environment for aviary farmers appeared to be more risky, which was indicated by more injuries during working among the hens in the hen-house. Apart from that, the poultry farmers with aviary houses reported more complaints in the previous period of 12 months about the locomotion organs (back spine, legs and arms) than their colleagues with a battery house. On other points there were no differences or only marginal differences between aviary and battery housing farms.

All useful information from the Dutch research carried out on the various disciplines, were brought together in a list of demands. This information can be used to improve and further develop aviary systems in the future with the goal to contribute to better working conditions for farmers in aviary houses (Lokhorst *et al.*, 1994).

Professional skill

The professional skill of a farmer can be divided into traditional husbandry skills like knowledge of bird behaviour, feed management, lighting programmes, disease prevention and recognition and litter management, and technical skills like knowledge of the equipment and manure management. The amount of professional skill required to manage a poultry farm depends on the housing system that is used and the rate of automation and mechanization. The more automation and mechanization is used, the more knowledge in these fields is required. From this point of view some systems are easier to handle than others. For instance, compared to cages much more traditional husbandry skills are required in alternative systems to battery cages. This despite the fact that many of these systems also have high rates of automation and mechanization.

3.5.5 Criteria for judging labour and organisation

Labour force

The best criterion for defining the labour efficiency of a housing system for laying hens is the number of hens that can be taken care of in that system by one full-time worker (ftw).

For systems which are widely used in practice, this number, including variation due to sample size, and to slight differences in equipment, working methods or labour performance, can be estimated by means of an enquiry among farmers. This can not be done for new systems, in which the number can be estimated approximately by means of measurements made in short-term trials. The number of hens per ftw is then estimated by the formula:

$$N = (p.A \times 1000) / (E.t1 + t2)$$

N = number of hens per ftw
A = number of working hours per day
E = egg production rate
t1 = time required by one ftw to collect and pack eggs, in hours per 1000 hens
t2 = time required by one ftw to complete daily bird inspection and survey rounds, including gathering floor eggs, in hours per 1000 hens
p = share of (E.t1 + t2) in total daily labour requirement, on the basis of total labour requirement per year (including periodical labour and work between flocks).

To simplify the formula A can be put at 7.5 hours and p can be put at 83% (Ehlhardt *et al.*, 1989a). The number of hens per ftw is then:

$$N = 6200 / (E.t1 + t2)$$

The number of hens which can be taken care of by one full-time worker does not only depend on the housing system. The rate of automation also has a strong influence and in non-cage systems the number of floor eggs plays an important role. Table 3.5.7 gives an overview of the number of hens per full-time worker for some housing systems. Due to continuously ongoing developments the number of hens per one full-time worker is still increasing.

Table 3.5.7. Number of hens managed by one full-time worker (2,200 hours/year).

Ref.	cages (low)	cages (high)	deep litter (low)	deep litter (high)	aviary (5% f.e.)	aviary (2% f.e.)	free
1		19,000		16,250			
2	16,500	27,750	7,000	12,250			
3		40,000					
4	17,500	32,000					
5		30,000		12,000	26,000		
6	18,000	31,000	6,500	15,000			
7		28,000					
8						25,750	
9		30,000		12,000	23,250	25,000	5 -
10		40,000		20,000	20,000		
11		28,500				23,250	
average	17,250	30,625	6,750	14,500	23,000	24,667	

References: 1) Anon, 1981; 2) Maton *et al.*, 1983; 3) Bell, 1985; 4) C.A.D.P., 1986; 5) Zaalmink, 1987; 6) C.O.V.P., 1988; 7) Ehlhardt *et al.*, 1989a; 8) Tucker, 1989; 9) van Horne, 1990; 10. Tucker, 1991; 11. Top *et al.*, 1995

Key: (low) = low rate of automation; (high) = high rate of automation

(2% f.e.) = 2% floor eggs; (5% f.e.) = 5% floor eggs

3.5.6 Summary

Labour requirements

Daily duties are by far the most important for determining the labour efficiency on egg production farms, since they make up 77-91% of total labour requirement.

The amount of labour needed depends mainly on the system used for collecting eggs. By using roll-away nests and egg belts, collecting of nest eggs can be as efficient as collecting eggs by belt in houses with cages. However, if hens are not kept in cages, there is always a problem with floor eggs, which makes egg collecting time unpredictable.

One full-time worker can handle less hens kept in an alternative system compared to the number of hens kept in a battery cage system. The actual number of hens kept in a system by one full-time worker is caused mainly by differences in mechanisation, automation and the number of floor eggs.

In terms of labour efficiency, the best housing system is a battery cage. However, it is not possible to inspect each bird each day in any system.

In systems using litter there are problems with floor eggs and these alternative systems to battery cages are therefore less predictable in labour requirement.

Labour organisation and working conditions

Labour organisation depends to a large extent on the housing system. In alternative systems to battery cages the presence of daylight is sometimes required. If natural daylight is applied, the farmer needs to adjust his working hours. The most flexible system from the point of view of labour organisation is an artificially controlled laying house.

There are significant differences between different farms in factors influencing working conditions. The time spent in the hen-house and, therefore, the exposure to dust and ammonia, depends on the housing system and the degree of mechanization. Open and long term manure storage inside the house and the presence of litter in the hen-house can cause problems with high levels of ammonia, dust, microorganisms and endotoxin, which make working conditions very bad. If optimal manure management is applied in both battery and alternative systems to battery cages, the litter is the main cause for worse air quality in the alternative systems.

Differences in housing systems cause differences in working postures, ease of moving, and the need for physical effort and special equipment.

In terms of labour, litter is undesirable, because it can cause higher labour requirements and poorer working conditions. However, possibilities are present to reduce the emission of ammonia effectively from litter and consequently lower ammonia concentrations.

In terms of working conditions the best housing system is a battery cage house with manure belts and a manure drying system. However, even in this housing system with relatively low dust concentrations the use of dust masks is advised to prevent health problems.

Professional skills

Battery cages are in general easier to manage than alternative systems to cages.

Alternative systems to battery cages require a very high standard of traditional husbandry skills to run these systems successfully, because the bird management is more difficult than in cages. Additional training and education are necessary to acquire these skills.

Highly automated housing systems require additional technical knowledge and skill.

Large farms require more skill to manage well.

Skill is required to observe and minimize the effects of feather pecking and cannibalism.

One of the main problems in litter systems is the presence and unpredictability of floor eggs. Good litter management needs to be developed. This is not only important in terms of labour requirement (fewer floor eggs), but also in terms of working conditions (dust, ammonia).

3.6 Environment

3.6.1 Introduction

Aspects

One of the major challenges in modernisation of animal production is the reduction or elimination of its polluting effects on the environment and the improvement of the air quality as a major parameter of the working and living conditions for man and animal respectively. The external effects of the housing of laying hens on the environment are described in this chapter. The internal effects of the housing system are described is chapter 3.4. Adverse effects on man and animal of the internal climate of the houses for laying hens are described in chapter 3.4 and 3.2.11 respectively.

The external environmental effects are related to:
1. Manure application and the nitrogen and phosphorus balance of a topographic area, region or country; surpluses can lead to eutrophication and ground water pollution.
2. Emissions of ammonia during storage and application of manure and ventilation of the animal house; deposition of ammonia can lead to acidification and eutrophication of e.g. woods.
3. Emissions of other gases as carbon dioxide (CO_2), methane (CH_4) and nitrogen oxides (NO_x), that are responsible for global warming, and emissions of odour (nuisance effect).
4. Energy consumption, what is related to the emission of carbon dioxide.

Possible alleys for progress are to be found in a new generation of housing and management techniques related to the handling and storage of manure and control of the internal climate. This chapter deals with the methods and principles applied and the evaluation of promising techniques or housing systems for laying hens.

Housing systems and manure handling

Laying cages generally have wire floors. This enables the poultry manure to fall into a storage system underneath the cages or onto conveyer belts. Battery systems can be classified according to the way the waste is managed, i.e. the type of waste and the removal and storage method (table 3.6.1) (Groot Koerkamp and de Haan, 1990; Priesmann *et al.*, 1990; Peter and Zacharda, 1977). The faeces can be treated to become slurry or dry manure. For the former, the faeces are eventually mixed with water and stored in a manure pit. The faeces fall directly into a manure pit underneath the cages or belts or scrapers can be used to transport the manure from the house regularly to a storage system, e.g. once or twice a week. This storage system can be situated in the basement or outside the animal house. The storage period can vary from several months to a year. In the case of dry manure, the faeces are dried, either in special channels underneath the cages (channel house) or in the whole basement of the house (deep-pit), either on the manure belts in the poultry house or in a special drying system separated from the chickens' living space. Drying decreases the volume of manure and reduces microbial processes. The evaporation of water is enhanced by air flowing over the manure. Especially in the first two ways (channel and deep-pit houses), the drying process is stimulated by means of composting of the manure. This takes place naturally until a stabilized product with a dry matter content in the range of 50 to 70% has been produced. However, manure composting encourages vermin (e.g. mice) and produces high concentrations of ammonia (Klarenbeek *et al.*, 1985). The stay of manure on belts or in a special drying system takes at most one week. After this drying process the manure is stored in sheds or is covered.

Table 3.6.1. Overview of housing systems for laying hens and manure handling.

Housing system	Waste		Storage system	
		dry matter content % wt/wt	treatment and location *	storage time year
Battery cages	Slurry	10-20	Open manure pit under cages	1
			Manure pit under house, outside	1
			Manure pit (covered over), outside	1
	Dry manure	40-70	Composting in channels	0.3
			Composting in basement	1
			Drying on belts	0.02
			Drying in special system, outside	0.01
			Storage in sheds or covered, outside	1
Alternative systems to battery cages	Slurry	10-20	As battery cages	
	Dry manure	40-70	As battery cages	
	Litter	60-80	Drying in scratching area	1
			Storage under sheds or covered,	1

* if outside: the emission from the storage system does not contribute to the emission from the animal

Welfare-oriented systems like aviaries and percheries are generally equipped with slatted or wire floors or perches over a manure pit or belts, and a litter area. Beside the manure, also litter is present (table 3.6.1). The manure is generally inaccessible for the hens and can be handled in the same way as in battery cages. The litter consists of faeces dropped in the scratching and dust bathing area mixed with the litter material initially present (e.g. straw, sand or wood shavings). Depending on the litter management, the litter consists predominantly of faeces or contains high C:N ratios due to adding of new litter. The litter generally has a relatively high dry matter content (60-80%) and a granular structure. Especially in deep litter systems, the scratching and dust bathing area also retains a manure storage function.

Various aspects of use and recycling of chicken manure have been discussed by Voorburg (1990). Despite some disadvantages (variable composition, unknown availability of nitrogen, risk of spreading weeds and pathogenic organisms) poultry manure is the most valuable livestock manure and is appreciated by arable farmers. During storage and use of manure, especially for dry poultry manure and litter, high emissions of ammonia can occur. So, for the emission of a housing system the sum of emissions from the housing and storage system and from manure application must be summarized.

Sources and processes

The production and composition of faeces (fresh droppings) are of major interest when studying environmental effects of poultry production. Table 3.6.2 gives ranges for faeces production and composition, representing a summary of published results (Ehlhardt and Janssen, 1987; Priesman *et al.*, 1990; Frenken, 1989; Leenstra and Pit, 1990). The nitrogen components uric acid, urea, ammonia/ammonium and undigested proteins are the potential sources for ammonia volatilization. Uric acid and undigested proteins are the two main nitrogen components in faeces, representing about 70% and 30% of the total nitrogen respectively. The dry matter content, acidity (pH), temperature and physical properties of the faeces are important process factors.

Table 3.6.2. Faeces production per hen per day and contents of dry matter and nitrogen components.

Faeces production	Dry matter content	Total N	Uric acid N	Urea N	Ammonium N	Undigested proteins/ residual N
g/(hen d)	g/kg	g/kg	% of total N	% of total N	% of total N	% of total N
160-180	200-250	13-17	60-75	0-3	0-3	25-34

The most important processes involved with the release and fixation of ammonia are the degradation of uric acid and undigested proteins, the ammonia-ammonium (NH_3/NH_4^+) equilibrium, and the volatilization of ammonia from the manure (table 3.6.3). Degradation of uric acid by microbiological processes has been extensively described by Vogels and Van Der Drift (1976), Burnett and Dondero (1969) and Carlile (1984). The effect of temperature, pH, water activity (A_w) and oxygen availability in the substrate on the degradation rate was modelled by Elliott and Collins (1982) and used for litter by Groot Koerkamp and Elzing (1996). Optimal conditions for release of ammonia are 35 °C, pH 9 and a moisture content between 40 and 60%. Lower dry matter contents reduce oxygen availability, higher contents reduce the availability of free water and hence the water activity. The volatilization of ammonia from manure highly depends on the air velocity and the pH: below pH 8 nearly all ammonia is ionized (NH_4^+), above 10 all ammonia is unionized (NH_3) and liable to volatilization. The volatilization of water from manure and litter influences the moisture content directly; this process is positively influenced by temperature and air velocity and negatively by water vapour pressure of the air.

Table 3.6.3. Schematic overview of processes and factors involved in ammonia release from poultry houses. T: temperature, pH: acidity, A_w: water activity, r.h.: relative humidity.

Processes	Nitrogen components and appearance	Affecting Factors
1. Faeces production ↓	Uric acid + undigested proteins	Animal
2. Degradation ↓	Ammonia / ammonium in manure	Process conditions (manure): T, pH, A_w
3. Volatilization ↓	Ammonia in air	Process conditions & local climate ⇕
4. Ventilation ↓	Ammonia in poultry house	Local climate (air): T, r.h., velocity
5. Emission	Ammonia in environment	Air cleaning

The following processes and circumstances may cause high emissions of ammonia:
a) composting of manure and litter, during drying or storage,
b) volatilization of ammonia from open storage of slurry,
c) high degradation rates in wet litter, in the house or during storage, and
d) manure and litter application.

To reduce ammonia emissions the following principles are considered to have the best chances of being implemented on commercial farms: 1) control of moisture content by means of drying and 2) reduction of ammonia volatilization by lowering contact time, contact area and air velocity. Both principles are based on the control of the local climate above the manure and litter. However, the control (increase) of air temperature and velocity, and also contact time and area, in order to enhance the drying process conflicts with the goal of reducing ammonia volatilization. But, due to the relatively slow degradation rates of nitrogen components in faeces, the amount of liberated ammonia will be small if the degradation process is minimized by the higher dry matter content (lower A_w value) within a sufficiently short period. Reduction of the moisture content of manure or litter to values under 30% will be very effective within the poultry house.

3.6.2 External effects

Manure application

Emissions of ammonia during manure application are high when traditional techniques like surface spreading of slurry are applied. Depending on the weather and soil conditions, 20-100% of the ammoniacal nitrogen applied, is lost from surface-spread slurry. New slurry application methods to reduce ammonia emission are developed and discussed with regard to the effect of reducing ammonia emission and their suitability for different soil types (Huijsmans *et al.*, 1992). The ammonia emission rate tends to be relatively high in the first few hours after application and to decrease rapidly during the day of application. The emission can be reduced by decreasing the exposed slurry surface to the air by, for example, incorporation the slurry into the soil. On arable land tilling directly after spreading reduced the area of the slurry surface that was exposed to the air. A range of techniques are available for burying or mixing slurry into the soil on bare arable land. The incorporation methods differ in their ability to reduce ammonia emission. Complete burying of the slurry by a plough or injection of the slurry reduced the emission by more than 90%. Incorporation of the slurry by a tine cultivator reduced the emission by 40-70%. Specifically for slurry and dry manure from poultry reductions of 70-80% can be achieved, depending on the tilling technique and weather circumstances (Mulder en Huijsmans, 1994). The effect of the time between spreading and incorporation on the emission for a practical working organisation with separated spreading and incorporation, was modeled for various situations by Mol and Huijsmans (1995).

An indirect way of manure application is encountered in case of free range systems where the hens have access to pastures. The phosphorus and nitrogen load on the pastures will depend on the stocking density, but can lead to high concentrations of phosphorus and nitrogen leaching as was found in case of outdoor housing of ducks.

Emissions of ammonia from houses and storages

Results of an EU-project (table 3.6.4) on aerial pollutants in animal houses in Northern Europe showed that emissions from housing systems for the same animal species vary considerably between countries, mainly due to differences in manure handling. The emission from housing systems with litter was much higher than from battery houses (Netherlands and Denmark), while long term storage of manure inside the house also caused high emissions (UK percheries and cages).

Table 3.6.4. Yearly mean emission of ammonia in mg/h per animal (g/a per animal between brackets) for two housing systems for laying hens in the United Kingdom, The Netherlands, Denmark and Germany (Groot Koerkamp *et al.*, 1996a).

Animal type and housing system	United Kingdom	The Netherlands	Denmark	Germany
Layers - deep litter/perchery	30.9 (237)	36.0 (276)	38.3 (293)	-
Layers - battery cages	39.4 (302)	6.4 (49)	7.7 (59)	2.1 (16)

Wachenfelt (1993) also showed emission rates of ammonia from battery cage houses between 4 and 10 $mg.h^{-1}$ per hen, which were much lower than the rates from the system with litter (14-18 $mg.h^{-1}$ per hen). Emissions during summer were up to twice as high as during the winter period.

The normative emissions from housing and storage systems in the Netherlands are generally based on research and laid down in legislative values (Anon., 1996). These ammonia emissions are given in table 3.6.5 and are expressed per hen place per year, using an occupancy rate of 14:16 (= 88%). The emissions from housing systems with storage of manure (composting) or slurry inside the house are the highest, being 386 and 83 g per year per animal. Emissions from different kind of battery cages with manure belts are much lower, 35 g per year per animal, and can even be further reduced. The emission from the traditional loose housing system with litter and manure storage inside the house, about 300 gram, lies far above the level of battery cages. The emission from standard aviary systems with manure belts and litter varies between 70 and 90 gram per hen per year. Both the higher level and the variation are caused by the emission from the litter. The 20% of the faeces dropped in the litter caused about 80% of the emission of ammonia from the TWF system (Groot Koerkamp *et al.*, 1995). Effects of the following factors on the emission from aviary systems were analyzed: removal frequency of the belt manure, litter management (litter removal and replacement) and outside weather climate. With none of these factor could the emission be reduced to the level of battery cages. However, drying of the litter in aviaries with a specially developed drying system increased the dry matter content up to 80-90% and reduced the emission effectively as shown by Groot Koerkamp (1995). Investment and operational costs of this drying system are not exactly known, because no commercial farm is using it yet. However, the costs are likely to be affordable for farmers. Ammonia emissions from housing systems for laying hens younger than 18 weeks are lower than the values mentioned in table 3.6.5. Reduction of emissions from housing systems for laying hens will cause extra costs for the farmers, and will depend on the specific circumstances.

Table 3.6.5. Ammonia emission from various housing systems and applied manure handling in gram NH_3 per year per hen place.

Housing/storage	Manure handling	Emission
Cages	dry manure in channels or deep-pit (composting)	386
Cages	slurry, open storage under cages	83
Cages	faeces on belts, removal 2 week^{-1} to closed storage	35
Cages	dry manure on belts (drying), removal 1 week^{-1}	35
Cages	dry manure/faeces on belts, improved drying and/or daily removal of	< 35
Deep litter	half litter / half slatted floor	178
Aviary	80% of manure on belts and regularly removed, normal litter conditions	70-90
Aviary	80% of manure on belts and regularly removed, drying of litter	< 35
Storage dry manure	in sheds or covered	50

Emissions of other gases and odour

Little or nothing is quantitatively known about the emissions of other gases from poultry production systems.

The odour emissions from, especially, large poultry farms can give rise to problems with local neighbours. Emissions of odour are probably related to emissions of ammonia, but the relation does not seem to be simple. The nuisance of odour is thought to be mainly caused by the evaporation of fatty acid from the manure (Mårtensson, 1995). He measured concentrations of various kinds of fatty acids, but no clear differences were found between the concentrations in the air of a battery cage and a loose housing system.

Emissions of dust from houses

Emission of respirable dust (small dust particles) from deep litter systems (half litter, half slatted floor) and battery cage systems were estimated to 2.3 and 0.14 mg.h^{-1} per hen respectively, based on measurements in commercial houses. The higher emission from the system with litter was mainly caused by higher concentrations of respirable dust (1.25 and 0.07 mg/m^3 respectively). The presence of litter in combination with the activity of hens was pointed out to be responsible for the differences (Groot Koerkamp *et al.*, 1996a).

3.6.3. Summary

Acceptable ammonia concentrations and the lowest emissions of ammonia are found in those systems in which complete and frequent removal of manure is possible and manure is stored outside the house. Cage systems with manure belts or scrapers (slurry or dry manure) can meet these requirements.

Unacceptable high concentrations were found in housing systems with litter (aviaries / deep litter systems) and battery cages with long term manure storage inside the house. Emissions from these systems are 3 to 10 times higher than from battery cages with belts.

Concentrations and emissions of ammonia from housing systems for laying hens vary considerably throughout Europe, mainly caused by differences in the applied manure handling.

Concentrations and emissions from housing systems with litter can be reduced to the levels of battery cages with manure belts.

The labour conditions (mainly ammonia and dust concentrations) in the aviary house are worse than in a battery cage house. Due to good management the exposed levels can be lowered, however, the wearing of good respirators is recommended, both in aviary and battery houses.

Reduction of the environmental load due to emissions of ammonia, carbon dioxide, dust or other aerial pollutants will in general inevitably lead to extra costs of the farmer.

3.7 Economics

3.7.1 Production Costs

For about 40 years, in most countries, laying cages have been the standard system of table egg production, and over 90% of eggs have been produced by hens kept in battery cages. Several alternative systems have come into use recently in which the eggs produced command a premium. Some of these are recent innovations, e.g. percheries and aviaries: others were in general use before laying cages became popular, e.g. deep litter and free range. The actual systems and the premiums they command vary from country to country.

That costs of production vary considerably between systems was demonstrated by Elson (1985) who compared a wide range of husbandry systems, both commercial and experimental. Elson drew his information from a range of sources, and by amalgamating the data and incorporating well-informed opinion where necessary, he produced the results shown in Table 3.7.1. Although it was prepared 11 years ago, the data presented is confirmed by recent studies - see Tables 3.7.3, 3.7.5 and 3.7.6. It is presented rounded and summarised in Table 3.7.7. Production costs are lowest in multi-bird cages.

Taking the cost of production as 100 for birds housed in laying cages at 450 cm^2/bird, the minimum required under Council Directive 88/166/EEC, (EC, 1988) it will be seen from Table 3.7.1 that greater space allowances in cages, as well as production in different systems, increase costs. Allowing birds more area in cages increases production costs by about 5% at 600 cm^2 and 15% at 750 cm^2/bird, housing in aviary/perchery systems by 8 - 15%, housing on deep litter by about 18% and in outdoor systems by up to about 50%. Other systems fall into intermediate categories.

These findings were confirmed by Haartsen and Elson (1989) who made a detailed analysis of production costs in cages, aviaries and deep litter - see Table 3.7.2; also by NFU (1995) who regularly collect production data from many UK egg producers - see Table 3.7.3. Tucker (1989) compared costs of production in cages, perchery and free range systems. The data are given in Table 3.7.4 and show costs in percheries at about 11% more, and in free range at about 52% more than in cages. Horne (1996) carried out a large scale survey of aviary systems and laying cages in the Netherlands. He concluded that the production cost for white hens in these high density aviaries (at 20 birds/m^2) was 8.2% higher than in laying cage houses (at 28 birds/m^2) - see Table 3.7.5.

As indicated in Table 3.7.1, the production of free range eggs, which sometimes attract a good premium, is considerably more costly than in any other system, especially if the value of land is included. However, land can sometimes be shared with other stock such as sheep or cattle. Also, land usually appreciates in value rather than depreciating like housing and equipment. Even if the land value is left out, free range egg production can still cost about 40% more than cage egg production. Some capital items like high fencing to exclude predators are expensive and certain running costs, especially the high feed intake in winter can be considerable.

In examining these costs of production, we need to consider what factors influence them. These include housing, stocking density, quality and quantity of labour, food intake, hygiene, mortality and predictability of performance(Elson, 1992). Several factors in alternative systems combine to make performance less predictable, thus increasing the risk of higher production costs. However, results from a Dutch study involving 19 flocks of white hens in aviaries and 47 flocks of white hens in cages indicated that variability was no greater in aviaries than cages (Horne, 1996); although not mentioned in the paper, it is understood that the birds in this study were beak trimmed as is normal in the Netherlands. Clearly the degree of management skill and attention to detail in any alternative systems will affect production costs, and high standards of management and stock inspection are recommended. Costs of production will, of course, be further increased if severe problems occur e.g. cannibalism; such problems are often unpredictable in alternative systems, and occur more frequently than in cage systems (Hughes, 1990).

The question has been raised as to what area/bird in cages equates in terms of production costs to housing in alternative systems. This is best answered by the estimates of Elson (1995) - see Table 3.7.6. These estimates are taken from large scale automated intensive systems; they indicate that at a stocking density of about 800 cm^2/bird in cages production costs are about the same as in high-density perchery or aviary systems. This assessment was confirmed by Horne (1991), who put the figure at about 750 cm^2/bird in cages - see figure 3.7.1., and by Blokhuis and Metz (1995) who suggested that the figure is about 850 cm^2/bird.

The most recent system to be developed is the Modified Enriched Cage (MEC) - see chapter 2. Since MEC's are still at the R & D stage, commercial scale costs are difficult to assess, and it is therefore not possible to provide accurate figures. However, costs of production in them can be expected to be considerably higher than in conventional cages at current stocking densities. With this proviso, Elson (1993) indicated that capital costs of MEC's might be as much as double that of conventional ones and "that together with consequent likely effects on the feed intake and labour requirements in particular, such radical cage enrichment might increase production costs by 10-20% - much of this being due to reduced stocking density". It now appears possible that slightly higher stocking densities may be achievable in MEC's and if so the increase in production cost is likely to be nearer 10%.

3.7.2 Consumer Attitudes

Bennett (1996), using a consumer survey of attitudes to laying cages, demonstrated that the contingent valuation method (involving willingness to pay extra) of estimating people's preferences can be applied to animal welfare issues. In this example a sample of 140 students at the University of California were interviewed. 72% stated that they would support legislation to ban cages and their willingness to pay extra varied from 0.10 to 0.8 $US/dozen eggs with a mean of 0.35$US (about 13% to 106% - mean 46%). However, those interviewed would not be buying eggs from retail outlets themselves.

The real test is, of course, how many consumers in society are willing to pay sufficient to cover the extra costs of production in a non - cage system. This varies from country to country and at present prices of eggs may not reflect production costs accurately.
The purchase of non-cage eggs does not necessarily indicate concern for animal welfare; some consumers are known to be willing to pay extra for bigger and what they perceive as better eggs, and the demand for smaller non-cage eggs is generally very weak.

3.7.3 Effects on EU Market

The most recent available complete data on the size of the EU population and of egg consumption per capita by country is given in Table 3.7.8, Bilans DGV 1 (1996). This reveals considerable variation between member states; the population is highest in Germany and lowest in Ireland whereas egg consumption is highest in Denmark and lowest in Portugal.

The vast majority of EU eggs are still produced by birds in cages - about 93% in 1995. However, because of demand in several member states particularly in Northern Europe, non-cage egg production has gained in popularity over the past ten years. Aviary, perchery, deep litter, semi-intensive and free range systems have developed and eggs from them command a premium price in certain areas. In Great Britain, for example, in 1995 87% of eggs were produced by hens in cages, 2% in percheries and 11% on free range. In the Netherlands aviaries and deep litter were more popular and 40% of the eggs *sold* there were non-cage (Bijleveld, 1996). In France the majority of non-cage eggs were produced in the semi-intensive system. In France and Germany less than 7% of the eggs produced in 1995 were non-cage, in Austria and Sweden the figure was about 12% whereas Denmark had the highest proportion at about 25%. However, it is reported that demand for non-cage eggs decreased in Denmark in the first half of 1996 (Agra Europe, 1996).

As far as Community trading is concerned, this is quite free between member states whereas import charges have been high on eggs imported from third countries. Until 1995 import levies were the most important instrument at the industry's disposal in the European egg market, which protected effectively against imports from outside the EU. When the new GATT agreement was implemented on 1 July 1995, import levies disappeared and were replaced by duties. Qvist (1995) indicated that these protect the industry at least as efficiently as the levies, but that they will be reduced by 6% a year over the implementation period of 1995 to 2000.

It has to be realised however that higher welfare standards in the EU would increase production costs as outlined above and make this market attractive for imports from third countries with lower welfare standards and production costs. So far, current EU welfare standards have not given rise to increased imports of eggs in shell even after the introduction of the low duty import quotas from 1 July 1995.

3.7.4 Summary

Costs of production are influenced by the housing system, stocking density, food intake, labour, hygiene, mortality and performance. At current stocking densities they are lowest in cages and highest in free range systems. MEC's are under development and costs of production in them are likely to be between current cages and alternatives, depending on stocking density.

At about 750 - 850 cm²/bird in cages production cost becomes about equal to a high density perchery or aviary system, but performance and therefore production cost is less predictable in the latter, except for severely beak trimmed white hens in some aviaries.

If higher welfare standards are adopted in the EU, production costs will rise and the EU market will become more attractive for eggs from third countries with lower standards. Protection against imports from such countries with lower welfare standards should therefore be provided. It is clear that high minimum welfare standards and free trade between EU member states and third countries are incompatible, and only one of these two principles can be followed at a time; this should be considered in future decisions.

Table 3.7.1. EGG PRODUCTION COSTS IN DIFFERENT POULTRY SYSTEMS (FROM ELSON, 1985)

SYSTEM	SPACE+	COST
Laying cage	450 cm²/bird	100
Laying cage	560 cm²/bird	105
Laying cage	750 cm²/bird	115
Laying cage	450 cm²/bird + perch	100
Laying cage	450 cm²/bird + perch + nest	102
Shallow laying cage	450 cm²/bird	102
Get-away cage 2 tier		110
Aviary	10-12 birds/m²	115
Aviary and perchery	20 birds/m²	105-108
Deep litter	7-10 birds/m²	118
Strawyard	3 birds/m²	130
Semi-intensive	1 000 birds/ha	135 (140)*
Free range	400 birds/ha	150 (170)*

\+ Space refers in cages to cage floor area, in houses to house floor area and in extensive systems to land area.

* (Includes land area)

Table 3.7.2. PRODUCTION COSTS IN ALTERNATIVE SYSTEMS (FROM HAARTSEN AND ELSON, 1989)

Cost price - per hen housed - in Dutch guilders. ■ On 2/9/96 1 guilder = 0.5 ecus.

	Cage	Aviary	Deep Litter
Pullets	7.50	8.00	8.00
Food	23.98	24.19	25.27
Animal health	0.03	0.10	0.10
Litter	-	0.10	0.35
Electricity	0.69	0.69	0.35
Water	0.12	0.12	0.12
Delivery costs	0.19	0.25	0.18
Bird depreciation	0.54	0.57	0.58
General costs	0.39	0.45	0.98
Housing costs	4.51	5.10	5.09
Labour costs	2.40	2.76	5.80
TOTAL	40.35	42.33	46.82
Slaughter revenue	2.07	2.26	2.38
TOTAL COSTS PER HEN HOUSED	38.28	40.07	44.44
PRICE / kg EGG	2.06	2.16	2.39
PRICE / 100 EGGS	12.76	13.35	14.77

Table 3.7.3. NFU Analysis based on Average costs in April 1995b
Total cost of production per dozen eggs (pence) ✚

	Cage	Barn	Free Range
	51.1	59.0	68.8%
% increase over cages		15.0	34.6

Table 3.7.4. PERFORMANCE AND COSTS OF PRODUCTION IN ALTERNATIVE SYSTEMS (AFTER TUCKER, 1989)

SYSTEM	Cages	Perchery	Free range
PERFORMANCE			
Eggs per hen housed	276	265	252
Food intake (grammes per bird per day)	115	116	135
Mortality (%)	5	5	8
Old hen weight (kg)	2.18	2.18	2.27
No of birds/poultry worker	20,000	10,000	2,500

COSTS OF PRODUCTION (pence per dozen eggs) ✚ On 2/9/96 100 pence = 1.25 ecus.

	Cages	Perchery	Free range
Food	25.6	27.8	32.8
Bird depreciation	7.9	8.4	8.6
Labour	1.5	3.2	13.3
Electricity	1.2	1.2	0.7
Medication	0.1	0.1	0.2
Other costs	1.1	1.2	1.3
TOTAL	37.4	41.8	56.9

Food @ £140/tonne Pullets @ £2.35 each Old hens worth 24.2p/kg

Table 3.7.5. Production costs (NLG ■) per hen housed in aviaries and battery cages (after Horne, 1996).

	Aviary	Battery cages
Variable costs	30.87	29.40
Fixed costs	11.22	9.48
Total costs	42.09	38.88
Production costs/egg	12.72	11.96
Production costs/kg.egg	2.09	1.93

Table 3.7.6. Estimates of Egg Production Cost in Modern Very Large-Scale Automated Systems - Elson 1995.

Total cost of production for dozen eggs (pence) +

	Cages @ 500 cm²/bird	Cages @ 625 cm²/bird	Cages @ 833 cm²/bird	Perchery @ 15.5 birds/m²	Perchery @ 11.7 birds/m²	Free range @ 11.7 birds/m² and 1,000 birds/ha
	47	51	58	59	62	68
% increase over cages @ 500 cm²/bird		9	23	26	32	45
% increase over cages @ 625 cm²/bird		------------------	14	16	22	33
% increase over cages @ 833 cm²/bird		------------------	-----------------	2	7	17

Table 3.7.7. Summary of Egg Production Costs in Different Systems.

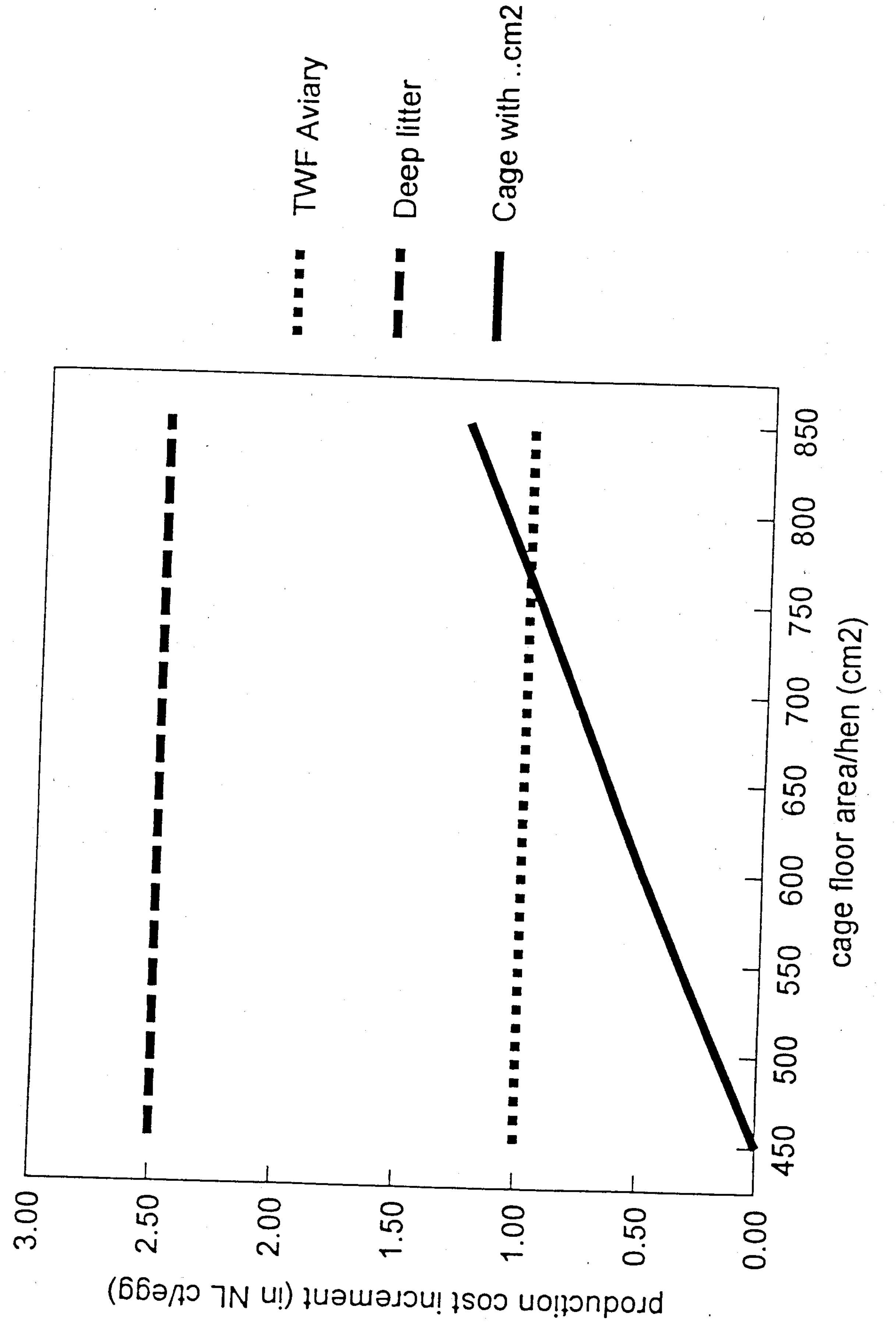
System	Stocking Density	Cost
Cage	450 cm^2 /bird	100
Cage	600 cm^2 /bird	105
Cage	800 cm^2 /bird	110
Aviary/Perchery	20 birds/m^2	110
Aviary/Perchery	12 birds/m^2	115
Deep Litter	7 birds/m^2	120
Free Range	1000 birds/ha.	140

Table 3.7.8. 1993 EU Population (x1000) and Egg Consumption (kg/capita)

COUNTRY	D	F	IT	NL	BL	UK	IRL	DK
POPULATION	81,179	57,655	57,049	15,290	10,483	58,191	3,563	5,189
CONSUMPTION	13.21	14.67	10.67	11.31	14.12	10.22	9.82	14.94

COUNTRY	GR	ES	PO	EUR 12	AUT	SU	FIN	EUR 15
POPULATION	10,379	39,083	9,876	347,937	9,992	5,067	8,719	369,714
CONSUMPTION	11.10	14.69	8.40	12.37	14.25	12.73	10.71	12.34

Figure 3.7.1. Comparison of production costs allowing more space per bird. The base of the figure represents the costprice per egg of 12 NLct in a battery cage with 450cm² per hen.



CHAPTER 4

EVALUATION OF DIFFERENT PRODUCTION SYSTEMS

4.1 Introduction

In the context of this report the evaluation of different production systems primarily deals with the welfare of the birds. However, other aspects of housing are also considered such as labour, environment and economics in order to make a more general assessment of the sort of systems which show most promise in relation to welfare as well as practical poultry production.

Several authors tried to assess welfare in different housing systems (e.g. Abrahamsson, 1996; Appleby and Hughes, 1991; Craig and Adams, 1984; Gerken, 1994, Hughes, 1990; Tauson *et al.*, 1992). Some of these studies were based on the author's own work, generally a comparison of two or three systems, and some were based on a broader evaluation of available data. For the purpose of this report the latter studies seem to be more valuable as these are not limited to specific experimental conditions or systems and have a more general validity. Although the welfare difference between some systems may be unequivocal it will be less clear in other comparisons because there are advantages to a system in some aspects and disadvantages in others. A problem then is the weighing of advantages and disadvantages.

A specific problem is that a system may be better when managed by one person than another. This is partly because one person is more skilled and dedicated than another but also because one system is more compatible with one person's interest than another.

An example of a welfare assessment was published by Hughes (1990). He provided an assessment of the relative welfare of birds in cages and 6 alternative systems in his paper "Welfare in Alternative Housing Systems for Laying Hens". It is based on a comparison of welfare aspects and the paper summarises the welfare benefits and dis-benefits of the alternative systems compared to cages. Hughes' personal conclusion was that "alternative systems now compare favourably with cages in welfare terms, but only if stockmanship is first class and only if commercial pressures to reduce costs and increase stocking densities are resisted".

On the basis of the information in foregoing chapters the pros and cons of different systems in terms of welfare as well as other aspects are summarised in paragraph 4.2.

4.2 Advantages and dis-advantages of different egg production systems

In this report scientific information and practical experience on welfare and health of laying hens in different production systems is reviewed. Also productivity, labour, environment and economics are considered.

There are many pros and cons in the various husbandry systems for laying hens. What follows is an attempt to summarise those for certain systems. The relative importance of each factor is not indicated but this list helps to give a broad outline of the relevant factors. It will be appreciated that there is much variation in practice and that many grey areas exist.

Advantages and disadvantages of cages and three classes of alternative systems are compared: enriched cages and non-cage systems, indoor and outdoor.

CAGES

ADVANTAGES

Welfare:

- Stable social order in small group sizes.
- No contact with manure, therefore minimal risk of endoparasitic infestations.
- Little risk of ectoparasites.
- No need to beak trim because risk of cannibalism is low.

Other aspects:

- Low labour requirement.
- Easy management.
- Cost efficient.
- Ammonia emission and concentrations can be controlled effectively.
- Levels of dust are relatively low.
- Hygienic for birds and eggs.

DIS-ADVANTAGES

Welfare:

- Degree of confinement prevents many behaviours including walking, running, roosting, flying, hiding, wing stretching, running plus wing flapping, wing flapping alone.
- Certain other behaviours are prevented or modified, e.g. dust bathing, nesting behaviour, scratching at litter or soil, pecking at litter or soil.
- No nesting facilities.
- Perching facilities absent.
- Low light intensity needed to control feather packing and cannibalism.
- Excessive claw length (can be reduced by abrasive strips).
- Featherloss can be bad (pecking and abrasion).
- No opportunity to escape victimisation.
- Brittle bones increasing risk of breakage at depopulation.

Other aspects:

- Inspection of birds requires great diligence.

ENRICHED CAGES

ADVANTAGES

Welfare:

- Stable social order if birds are in small group sizes.
- No contact with manure, therefore minimal risk of endoparasitic infestations.
- Nesting facilities.
- Limited facilities for dust bathing are sometimes available.
- perching facilities usually present.
- No need to beak trim because risk of cannibalism is low (if group size is low).

Other aspects:

- Ammonia emission and concentrations can be controlled effectively.
- Levels of dust are relatively low.

DIS-ADVANTAGES

Welfare:

- Degree of confinement prevents many behaviours. These may include walking, running, flying, hiding, running plus wing flapping, wing flapping alone.
- Certain other behaviours prevented or modified, e.g. dust bathing, scratching at litter or soil, pecking at litter or soil (not if dustbath or scratching area is provided).
- If colony size increases (such as in get-away cages) there is a tendency for aggression and the risk of feather pecking and cannibalism to increase.
- Excessive claw length (can be reduced by abrasive strips).
- Low light intensity needed to control feather packing and cannibalism.
- Featherloss can be bad.
- Some opportunity to escape victimisation.
- Brittle bones increasing risk of breakage at depopulation.

Other aspects:

- Inspection of birds requires great diligence.
- Could be less easy to clean.
- Level of servicing facilities (nest, dustbath) is higher.

<u>NON-CAGE SYSTEMS, INDOOR</u>

Deep litter, with or without perforated floor

ADVANTAGES

Welfare:

- Scratching and dust bathing possible.
- Birds can select nest site.
- Birds can exercise in a large variety of ways.
- Perching is usually possible.
- More space and freedom of movement.
- Bones stronger due to increased activity.

Other aspects:

- Easy to inspect birds.

DIS-ADVANTAGES

Welfare:

- Contact with droppings increases risk of coccidiosis and ascaridiosis.
- Ectoparasites more of a problem.
- Possible need to beak trim.

Other aspects:

- Floor laying can be a problem.
- Litter is costly and difficult to manage in winter.

- Higher standard of management required.
- More difficult to depopulate.
- High production costs due mainly to higher feed and labour costs.
- Less easy to disinfect and disinfest (depends on material and design).
- Rodents more prevalent.
- Dust levels are high.
- Ammonia concentration and emission are very much higher than in battery cages with frequent manure removal (although technical solutions for this disadvantage are under development).

Aviaries and percheries

ADVANTAGES

Welfare:

- Scratching and dust bathing usually possible.
- Birds can select nest site.
- Birds can exercise in a large variety of ways.
- Perching is possible.
- More space and freedom of movement.
- Bones stronger due to increased activity.

Other aspects:

- Better feed utilisation than in deep litter as result of reasonable temperature control.
- Fairly high stocking density possible, giving reasonably economic production - if birds perform well.

DIS-ADVANTAGES

Welfare:

- Bone damage during lay, particularly keel bone and wings.
- The risk of feather pecking and cannibalism is high if birds are not beak trimmed.
- Greater risk of coccidiosis and ascaridiosis.
- Birds may get contaminated when perches are arranged in tiers.

Other aspects:

- Very high standard of management required.
- Floor laying and floor egg collection can be a problem.
- Can be very difficult to depopulate.
- Less easy to disinfect and disinfest (depends on material and design).
- Dust levels are high.
- Ammonia concentration and emission are much higher than in battery cages with frequent manure removal (although technical solutions for this disadvantage are under development).
- Inspection of birds requires great diligence.
- Rodents more prevalent.

NON-CAGE SYSTEMS, OUTDOOR

ADVANTAGES
Welfare:

- As aviaries and percheries or deep litter plus:
- Birds that go outside have more freedom (possibilities to eat grass, insects etc.) and more space.

DIS-ADVANTAGES
Welfare:

- As aviaries and percheries or deep litter plus:
- Predators can cause losses, injuries and fear.
- Increased risk of exposure to parasites.
- Mortality levels usually higher.
- Extremes in temperature may cause severe discomfort.

Other aspects:

- As aviaries and percheries or deep litter plus:
- Higher labour requirement.
- Those birds that go outside get dirty causing additional litter problems and dirty eggs.
- Birds need shutting in at twilight.
- Land management skills required.
- High feed intake and higher production costs.
- Pollution from pasture is not controllable.
- Disinfection and disinfestation of pasture is very difficult.

4.3 Summary

Current battery cage systems provide a barren environment for the birds. Birds are for instance not able to show all normal movements, to obtain adequate exercise to prevent bone weakness, or to lay their eggs in a nest. A better system for housing hens is clearly needed.

A major problem encountered in many alternative systems is feather pecking and cannibalism. When beaktrimming is applied under high skilled management this problem can be controlled. If feather pecking and cannibalism is not controlled results in terms of welfare and productivity are less predictable in alternatives to cages.

Acceptable ammonia concentrations and the lowest emissions of ammonia are found in those systems in which complete and frequent removal of manure is possible and manure is stored outside the house. Cage systems with manure belts and/or scrapers can meet these requirements. Concentrations and emissions from housing systems with litter can be reduced to the levels of battery cages with manure belts.

At the current stage of development, production costs, labour requirements and the degree of management skill required are all higher in alternative systems than in laying cages. With many types of systems in use, there is inevitably much more variation in performance in alternatives than in laying cages.

Design of alternative systems to cages as well as specific management skills are gradually being improved on the basis of research and practical experience. Also cage design has been improved in recent years, and research and development on cage enrichment continues.
At present there is no ideal commercial system for laying hens from a welfare point of view. Further development is necessary in all systems but enriched cages and well designed non-cage systems have already been shown to have a number of welfare advantages over battery cages in their present form.

CHAPTER 5

ONGOING RESEARCH ON THE WELFARE OF LAYING HENS IN EUROPE

Denmark

At the Danish Institute of Animal Science, Research Centre Foulum the influence of environmental factors, and genetics on feather pecking in laying hens is investigated. The different types of pecking behaviour are studied with regard to high and low light intensity. Problems related to nest site selection, nest design and position are being investigated. Basic research on causation of feather pecking with special reference to dust-bathing takes place at The Royal Veterinary and Agricultural University in Copenhagen. On the basis of the theoretical models proposals to reduce feather pecking are developed and he results from this basic research are at the moment applied in commercial production. Basic research takes place at RVAU also on the ontogeny of behaviour in chickens with and without a hen mother, with special reference to synchronization of behaviour and social learning of substrate preference for dust-bathing. Ontogeny of the use of perches is also considered.

France

A study on productivity, physiology and behaviour is being carried out at the Centre National d'Etudes Vétérinaires in Ploufragan. Cage spaces from 450 to 800 cm^2 per bird and different heights (40 and 60 cm), and the use of perches in the higher cages are tested.
Basic research on fear and social behaviour is being undertaken at the SRA, INRA Tours, Nouzilly. Japanese quail, as models for the domestic chicken, have been selected for Tonic Immobility (fear) and Social reinstatement. The behavioural and physiological reactions are tested under various environmental stimuli related to management and welfare. Also the selection of cage space by operant conditioning technique is being investigated in adult laying hens.

Germany

The development of a perchery system is using productive, behavioural and health parameters is being undertaken at the Institute for Small Animal Research Celle. Special attention is paid to the ability of getting up and down to the different tiers at different horizontal and vertical distances of the perches. The influence of the position of the perches on the use of the different tiers and nest boxes, as well as on accidents leading to bone fractures are being investigated. Work on enriched cages is also carried out.
A special device has been developed to measure the use of dustbathes in individual hens in loose house systems. First results indicated considerable variation among birds.
Experiments on the genetic basis of feather pecking and cannibalism are carried out in the Institute of Animal Husbandry and Breeding, Dept. for Small Animals, University of Hohenheim, Stuttgart. Full- and half-sib groups of pullets are being observed visually during

the rearing and laying period. A special test has been developed to measure the pecking activity to feather dummies for layers in individual cages.

The Netherlands

The Centre for Poultry Research and Extension Services in Beekbergen is amalgamated with three other institutes in the DLO Institute for Animal Science and Health (ID-DLO) and is moved to Lelystad. Research related to the development of a competitive aviary system in recent years showed that aviary housing is an applicable, animal-friendly husbandry system to be used in practice, with the condition that the higher costs of the eggs be compensated in a certain way. Apart from that, more research and practical testing will be needed to find solutions for technical bottle-necks. In this respect, a better control of the dust concentration, reducing the percentage of floor eggs and restriction of the risks of feather pecking are the most important subjects.

Fundamental and strategic research related to welfare of laying hens, is being carried out at the Agricultural University in Wageningen and at ID-DLO Lelystad, e.g. on emotional expressions (sounds), on the development and causation of feather pecking and related physiological responses and the identification of genetic strategies that could lead to prevention or alleviation of skeletal problems.

The Centre for Applied Poultry Research in Beekbergen is involved in testing of improvements of the battery cage and testing of enriched cages.

Basic research on the utilization of vocalization in the chicken is being carried out at the Dept. of Animal Husbandry , section Ethology, Wageningen Agricultural University. Changes of the temporal structure of calls in response to different environment conditions, e.g. food deprivation are analysed.

Sweden

Most research is being carried out within four departments at the Swedish University of Agricultural Sciences. Three of these departments are also involved in the on-farm evaluation of different alternative housing systems on behalf of the Swedish Board of Agriculture.

In the Department of Animal Nutrition and Management at Funbo-L.vsta, applied research is being carried out on effects of different housing systems and hybrids on production, egg quality, health and behaviour (traits). Studies focus on system related problems (misplaced eggs, bumble foot syndrome, keel bone deviations, etc.) to help develop details in alternative housing systems e.g. perch and nest designs implying also development of different alternative systems per se.

At the Department of Animal Hygiene in Skara both basic and applied research is carried out on bird behaviour and health. Ethological studies have focused on social behaviour (social facilitation, effects of group size, presence of males etc.) and behaviour problems (mainly feather pecking and cannibalism). Health studies are related to clinical observations and the effects of rearing, stocking density, hybrid etc.

The Department of Agricultural Biosystems and Technology in Lund is involved in a project to determine size factors affecting the release and concentrations of air contamination and thereby develop techniques to reduce emissions in poultry houses. Investigations have also been made on the design and inventory of production systems for laying hens housed on floor at low stocking densities. Even research in ergonomic and accident risks are ongoing.

In the Department of Veterinary Microbiology research involves studies parasites, i.e. coccidia and poultry red mites. Studies have been carried out on parasite prevalence and population dynamics in alternative housing systems. Present research focuses on treatment and control methods. These investigations include the effect of vaccination against poultry coccidia and the application less hazardous chemical alternatives of ectoparasiticidal drugs.

Switzerland

Commercial production systems and equipment for laying hens are being tested by Bundesamt für Veterinärwesen, Zollikofen, with regard to their influence on behaviour, performance and health of the birds. The effect of feed structure and composition (pellets, crumbles, meal, expansion, crude protein level) on feather pecking and cannibalism of layers is being studied at the department of animal nutrition of the ETH, Zurich.

United Kingdom

The UK has traditionally been very active in research related to the welfare of laying hens. This research has covered the whole spectrum from basic research to applied studies and the development and testing of alternative housing systems.

Basic research into behavioural needs, cognitive processes and effects of stress is been carried out at the Roslin Institute and Universities at Edinburgh, Bristol and Oxford. In particular the motivation for dustbathing and nesting behaviour and aspects of social recognition and fear are studied.
Other work related to specific aspects of housing in alternatives to the battery cage is been carried out at Roslin, Bristol and the West of Scotland College of Agriculture. Topics include feather pecking, placement of perches and nest design.

The development and testing of new systems is been carried out at Gleadthorpe, West of Scotland College of Agriculture and the University of Bristol. Most effort is been directed towards large scale testing of enriched cages. However, some work is also continuing on aviaries/percheries and free range systems.
Studies of egg shell structure and quality in birds kept under different conditions are been carried out at Glasgow University. Research at Bristol and Roslin is investigating aspects of bone strength, bone breakage and transport.

CHAPTER 6

CONCLUSIONS

The following conclusions are presented in the light of the current state of knowledge and practical experience concerning production systems, strains of bird and other relevant factors.

They are based primarily on bird welfare considerations: other important elements such as labour aspects, production costs and environmental effects have been taken into account but have not taken precedence.

In order to promote good welfare it is important that housing environment and management allow those behaviour patterns which birds are motivated to perform as well as ensuring good bird health.

1. Laying hens must have at least daily access to food and access to water at all times.

2. Laying hens must have appropriate protection against predators and extreme climatic conditions.

3. Hens have a strong preference for laying their eggs in a nest and are highly motivated to perform nesting behaviour.

4. Hens have a strong preference for a littered floor for pecking, scratching and dust-bathing. When litter is provided it should be maintained in a friable condition. The provision of litter can reduce the risk of feather pecking.

5. Hens have a preference to perch, especially at night. If perches are provided they are generally well used and contribute to bone strength. Stronger bones decrease the risk of bone breakages, particularly when birds are taken out of the house and transported.

6. All resources should be provided in sufficient quantity and with an appropriate distribution in the system to minimise competition. Such resources should be designed and provided according to the management system, early experience and strain of bird.

7. Light should be sufficient to allow behaviours which the birds are highly motivated to perform. Since the variety of behaviours shown in darkness is limited, an adequate period of light should be provided each day. There is no scientific evidence that daylight is necessary for the bird's welfare.

8. Hens have been selected principally for being kept in battery cages. There should be selection of strains which are better adapted to other systems.

9. Current battery cage systems provide a barren environment for the birds. Important benefits and deficiencies of the battery cage with respect to the welfare of the hens include the following.

Benefits in comparison with good examples of other systems are:

- the birds are separated from their manure so endoparasitic infestations are rare;
- birds are in small groups with a stable social order;
- the risk of cannibalism is low and there is no necessity for beak trimming.

Deficiencies in comparison with good examples of other systems are:

- nesting behaviour, perching, scratching, dust-bathing and most movements are prevented or modified;
- stereotyped behaviour occurs;
- increased fear;
- bone weakness caused by lack of movement.

It is clear that because of its small size and its barrenness, the battery cage as used at present has inherent severe disadvantages for the welfare of hens.

10. To retain the benefits of cages and overcome most of the behavioural deficiencies modified enriched cages are showing good potential in relation to both welfare and production.

11. Housing systems such as aviaries, percheries, deep litter or free range provide varying degrees of enrichment.

Benefits in comparison with conventional cages are:

- improved possibility for the birds to express a wider range of behaviour patterns;
- bones stronger due to increased activity.

Deficiencies in comparison with conventional cages are:

- the risk of feather pecking and cannibalism is high if birds are not beak trimmed;
- higher risk of ecto- and endo-parasitic infestation;
- potential risk of bone breakage during the laying period.

It is clear that mainly because of the risk of feather pecking and cannibalism, these systems have severe disadvantages for the welfare of laying hens.

12. All beak trimming, the present main control method for feather pecking and cannibalism, should be banned as soon as practicable since it is known to cause pain both during and after the operation. However, while it continues, beak trimming in

adults is unacceptable and the procedure should only be carried out at a young age. Alternative systems, rearing methods and strains of bird should be sought in which feather pecking and cannibalism do not occur.

13. It is difficult to draw firm conclusions on space requirements because they vary according to the resources included in the space and to the group size. Individual birds need more area for certain activities than the 450 cm^2/bird currently required in battery cages. When kept in groups they can share space for behaviours which occupy only a small proportion of their time.

14. Cages for laying hens should be required to have a fully-opening cage front or an equivalent opening in another part of the cage. For four tiers of cages or more, a fixed catwalk or other approved device should be provided to allow inspection of the upper cages and to facilitate removal of birds from those cages. Methods of improving inspection of the bottom tier of cages should be implemented.

15. In systems allowing hens access to the outside, buildings should have an appropriate pophole area per bird spread evenly along the length of the house. Birds in these systems should have access to vegetation, shelter and shade outside the building. The access and stocking density on pasture should be chosen according to the soil type, pasture management system and climate.

16. Dust levels, ammonia concentration and emission are all lowest in battery cage systems with frequent manure removal.

17. Concentrations and emissions of ammonia in housing systems with litter are generally higher than in battery cages but can effectively be reduced by newly developed techniques.

18. Birds in all housing systems should be managed only by staff who have been trained and are experienced in the husbandry system used. In order to safeguard their welfare, the birds and any equipment upon which their welfare depends, should be thoroughly inspected at least twice per day.

19. In some studies egg production in alternatives to the battery cage is as good as that in battery cages. Nevertheless, at the current stage of development, production costs, labour requirements and the degree of management skill and veterinary supervision required are all higher in alternative systems. This means that a premium of between 10% and 50% (depending on type of system) on the egg price above the price of battery eggs is necessary to make these systems economically viable.

20. In some countries there is a strong increase in the sales of non-cage eggs, demonstrating that a small but increasing number of consumers are prepared to pay a premium. Public awareness of animal welfare and marketing strategies have influenced

this.

21. High standards of laying hen welfare can only be implemented and sustained if the EU market is protected against imports of eggs from third countries with lower standards.

22. Applied research into the welfare of laying hens has been undertaken for a relatively short period. Some disadvantages of alternative systems should be overcome during practical trials of existing systems under commercial conditions. Other problems, especially the major problem of feather pecking and cannibalism, need further research.

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