PRODUCTION AND BEHAVIOUR OF FOUR STRAINS OF LAYING HENS KEPT IN CONVENTIONAL CAGES AND A FREE RUN HOUSING SYSTEM

by

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Abstract

Production, egg quality, behaviour, and physical condition were compared from Wk 20 to Wk 50 among three beak- trimmed commercial laying strains, Lohmann White (LW), H & N White (HN), Lohmann Brown (LB), and a non-commercial Cross between Rhode Island Red (male) and Barred Plymouth Rock (female) in conventional cages and in floor pens. All chicks were reared in their respective environments, and 450 and 432 pullets were housed at 18 and 7 weeks of age in cages and floor pens respectively. Hens in cages were provided with 688 cm^2/bird and those in pens with over 6,000 cm^2/bird, both of which are more than provided by commercial standards.

Body weights and eggshell weights were higher for birds in floor pens than those in cages, and although they increased with age, body weight of hens in cages decreased at Wk 50. White-egg layers (LW, HN) used perches and nest boxes more than Brown-egg layers (LB, Cross). During the laying period, mortality was higher for all strains in cages and during the rearing period mortality was higher in floor pens for LB hens but not other strains. No aggressive behaviours were found, but the frequency of gentle feather pecking and pecking at the enclosure was higher in cages than in floor pens.

Feather condition deteriorated over time in cages mainly because of contact with the cage wires whereas in floor pens, feather condition of birds at Wk 20 was not different from that at Wk 50. The frequency of keel bone deformities was higher for White-egg layers than for Brown-egg layers in cages and was higher for Cross hens than other strains in floor pens. Claws were longer in cages than in the floor pens. Foot condition was worse in floor pens than in cages.

The welfare indicators used in this study showed that cages restricted the hens' behaviour compared to floor pens and resulted in higher laying period mortality, reduced body weight and deteriorated feather condition than floor pens. Both systems had advantages and disadvantages

in regard to the hens' health and welfare. The use of environmental complexities was strain specific in floor pens. The environment by genotype interactions suggests that the strain should be considered when considering alternative housing systems.

Table of contents

List of tables

List of figures

List of abbreviations

Cross	A cross between Rhode Island Red (male) and Barred Plymouth Rock (female)
BW	Body weight
LB and Cross	Brown-egg layers
LW, LB and HN	Commercial strains
DC	Door Corner
EC	Egg component
E. coli	*Escherichia coli*
HN	H & N White
H	Hour
NB	In nest-box
LB	Lohmann Brown
LW	Lohmann White
NBC	Nest box corner
Cross	Non-commercial strain
pg/mg	Pico gram/ milligram
UNB	Under nest box
Wk	Week
LW and HN	White-egg layers

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Dedication

To my

Children, Tanya & Tushar

&

*my supervisor, Fred G Silverside*s

Co-authorship statement

All the experiments and analysis were completed by me, Renu Singh. The following authors are listed on the manuscripts: Drs. Fred G. Silversides, Kimberly M. Cheng, and Ruth C. Newberry. The co-authors were involved in the preparation of manuscripts included in this thesis. In addition, Dr. Fred G. Silversides helped me in the analysis of data.

CHAPTER 1. LITERATURE REVIEW

1.1 Introduction

Laying hens are domesticated descendants of the red jungle fowl (*Gallus gallus*) that lives in Southeast Asia. They have been domesticated for 6,000 to 8,000 years and most of the time were kept for decorative or fighting purposes. During the last 1,000 to 2,000 years chickens have been reared for egg production. In the last 50-60 years, layer hen housing has changed from small scale and extensive to large scale and intensive using cage systems that produce a great number of eggs at a lower cost. Conventional cages brought a dramatic reduction in labour and ecto and endoparasitism and allow higher stock densities but contributed to compromising poultry welfare by providing a barren environment (Brambell, 1965) and increased fear, stereotypical behaviour, and bone weakness while reducing the behavoural repertoire (Mills and Wood-Gosh, 1985; Knowles and Broom, 1990; Appleby and Hughes, 1991; Jones, 1996). Due to concerns for hen welfare and growing consumer demand for speciality products from cage-free birds, use of alternative production systems is growing rapidly.

Alternative housing systems comprise free run, free range, percharies or aviaries, and more recently furnished cages. Free run housing is an entirely indoor method of housing. It is not necessary to provide more space for the layers in free run housing compared to conventional cages and provision of resources like nest boxes, perches, or substrate for dust-bathing are optional. Free range systems and sometimes percharies include outdoor access. Furnished cages are similar to conventional cages but contain perches, nest boxes, a litter area, and typically more space per hen. Bird genotype, group size, and the possibility to beak trim or use certain medicines, especially for ecto and endoparasitism, vary with different housing systems.

The environment contributes to the well being of an animal. Zimmerman et al. (2006) and Rodenburg and Koene. (2007) found an effect of management and design of housing on the adaptation of laying hens, but genotype also plays a great role (Wall, 2003). Choosing right genotype for the housing type may reduce some risks for layers, given that there can be great differences in behavioural profiles between commercial strains (Anderson et al., 2004). In addition, genetic predispositions may be expressed differently in different housing environments, resulting in more severe welfare problems in one system than another (Newberry, 2004) depending on the genotype. The genotype and phenotype of an animal helps in its behavioural adaptability (Lamont, 1994; Mench and Duncan, 1998).

Taking bird health and welfare into consideration, alternative housing systems for laying hens are also designed to balance the needs and profitability of the producer, the consumer, the industry, and the environment. Providing more space and offering environmental complexities in alternative systems allows hens to express their full behavioural repertoire (McLean et al., 1986; Appleby and Hughes, 1991) and improves some aspects of the physical health of hens (Rönchen et al., 2007) when compared with conventional cages. However, these advantages must be balanced against higher potential risks of elevated levels of ammonia (Groot Koerkamp et al., 1998), greater labour costs, and unhealthy working conditions (van Horne, 1994), and cannibalism (Newberry, 2004). Non-cage systems require special knowledge and often include higher potential risks than conventional cages in production and health of layers. Also, there is a need to understand the relationship between the genotype and its environment to prevent harmful behaviours, increase productivity, and improve welfare. However, there is considerably less research on non-cage systems than on cages for laying hen production. The major emphasis of research on non-cage systems has been solving practical problems, rather than developing an understanding of some of the principles through a systematic scientific approach. Hence, it is imperative to investigate different strains of laying hens' production, behaviour, and physical health traits in conventional cage and free run housing system to address these issues.

1.2 Production

1.2.1 Space allowance

The production codes of practice in different countries provide a range of different floor space from 450 cm^2 to 550+ cm^2 for laying hens in conventional cages (Animal welfare report, 2005). For example, the European Union has banned the use of conventional cages after 2012, after which only furnished cages with a floor space of 750 cm^2 will be permitted, with a usable area of 600 cm^2 in them. Recently in the USA, under Proposition 2, the California constitution amended the law to allow hens raised in confinement to lie down, extend their wings, and move freely.

In Canada, the British Columbia Specialty Egg Certification Program for Free-range and Free-run and British Columbia Society for the Prevention of Cruelty to Animals (BC SPCA) Certified Standards for Raising and Handling of Laying Hens recommend a floor space of 1,845 cm^2/ bird and 1,647 cm^2/ bird respectively from 20 wk of age for hens kept in free run housing systems.

1.2.2 Inter-relationship between body weight, feed consumption, and feed efficiency

Growth is a complex biological process and variation in the body weight of diverse poultry populations has resulted from genetic factors (Siegel, 1962; McCarthy and Siegel, 1983) and environmental circumstances. Selection in laying hens in the past four decades has resulted in the decline of body weight from older stock to the more current commercial strains (Fairfull and Gowe, 1986), and feed consumption has decreased along with a concurrent increase in feed efficiency (Jones et al., 2001). In addition, management of housing systems for laying hens has considerable influence on production traits such as egg weight, feed efficiency, daily feed consumption (Taylor and Hurnik, 1996; van Horne, 1996; Süto et al., 1997).

1.2.3 Egg quality and hen

Avian eggs constitute a natural balance of essential nutrients in the human diet. Egg quality is important for consumer appeal and the economic success of a producer depends on the total number of eggs sold. Thus emphasis is given to improve the egg quality. The external and internal quality of eggs is influenced by bird strain, bird age, disease, management practices, housing conditions, disturbance or stress. A number of these factors interact and because of these interactions, the causes of egg quality problems are often difficult to diagnose. Egg quality includes a number of aspects (Stadelman, 1977), related to the shell (external quality) and the albumen and the yolk (internal quality).

1.2.3.1 External egg quality

The external quality is evaluated on the basis of cleanliness, shape, texture, and eggshell quality. Cleanliness of eggs depends on the egg laying habbits of the chicken (Appleby, 1991). Even with nest boxes available, some hens will lay their eggs on the floor, and these floor eggs contribute substantially to the problem of soiled and dirty eggs, which is one of the major disadvantages of non-cage systems. Regardless of the housing system, bacterial contamination of eggs has to be taken into consideration (De Reu et al., 2006).

In general, the laying hen is genetically capable of placing only a finite amount of calcium in the shell. As hen ages, the proportion of shell decreases with the increase in egg size because a similar amount of calcium is spread over a larger surface. There are direct and indirect methods of measuring eggshell quality. Shell weight, an indirect method, may be measured by breaking the egg, washing the shell, drying them at room temperature for one day and then in a drying oven for 4-5 days at 100°C, and weighing.

1.2.3.2 Internal egg quality

Internal egg quality is largely determined by the albumen. Thinning of the albumen is a sign of quality loss. When a fresh egg is carefully broken onto a smooth flat surface, the round yolk is in a central position surrounded by thick albumen. When a stale egg is broken, the yolk is flattened and often displaced to one side and the surrounding thick albumen has become thinner, resulting in a large area of albumen being collapsed and flattened to produce a wide arc of liquid. This is the principle that is used in measuring Haugh units (HU), and is still commonly used to judge albumen quality (William, 1992). However, Silversides et al. (1993) reported that the HU correction is not sufficient for comparing fresh eggs from different flocks as it is influenced by the age and strain of the bird. Yolk quality is comprised of two components, the yolk color and the perivitelline membrane, which surrounds the yolk and deteriorates in storage causing the yolk to break more easily (Kirunda and McKee, 2000). The yolk color is important for the consumers (Nys, 2000), and depends largely on the diet (Leeson and Summers 1991).

Overall, egg quality has a genetic basis and the parameters of egg quality vary between strains of hens (Curtis et al., 1985; Silversides et al., 2006). However, egg quality is also influenced by the housing system under which the hens are kept (Mench et al., 1986; Vits et al., 2005) as well as by the age of the laying hens (Silversides et al., 2006). With an increase of age of the hen, egg, albumen, and yolk weights increase while the albumen height decreases, and there is little or no effect on shell weight (Hill and Hall, 1980; Silversides and Scott, 2001; Silversides et al., 2006). Fletcher et al. (1983) reported that with an increase in age of the bird, the egg yolk increases and adds a major component to egg weight whereas albumen weight also increases but is less influenced by the age.

1.3 Behavioural profiles

Providing more space in alternative housing systems increases the possibility of performing a greater variety of behaviours (Appleby and Hughes, 1991), whereas space restriction in cages adds to the significant restraint of behaviours leading to the reduction of welfare of hens (Dawkins and Hardie, 1989). But behaviour patterns that feral birds perform in the wild are not necessarily required in captivity for birds to have a good welfare and therefore observations of behaviour of birds can be a good indicator of the behaviours they are motivated to carry out.

Dawkins and Hardie (1989) believe that a minimum space requirement for a medium hybrid hen at rest is 475-600 cm^2 depending upon posture, but is more when hens are active. A hen is thought to perform two types of behaviours: small-scale actions, which include performance of behaviours such as feeding, drinking, sitting, standing, and preening and large-scale actions such as movements from one place to another, wing flapping, and wing stretching. Conventional cages, having less space may restrict even small-scale behaviours, which can have deleterious effects on the health of birds.

1.3.1 Maintenance behaviours

1.3.1.1 Feeding behaviour

Feeding behaviour does not occur randomly, but depends upon many factors including the photoperiod at which the laying hens are kept. At a photoperiod of 14-17 h, hens show marked rhythms in feeding, with a peak in the morning, and another before the artificial dusk (Savoury, 1976). The evening peak is more pronounced in laying hens than in non-laying hens on a day of egg formation, as the laying hens receive cues regarding formation of egg, such as an increase in calcium requirement (Hughes, 1972). Feeding behaviour also depends on the form of diet. Laying hens on a mash diet spend more time feeding than on pelleted diet, although the consumption of total food may be similar in both cases, which has been considered to be an advantage for feeding mesh (Fujita, 1973), because more time spent feeding reduces feather pecking or cannibalism which are major issues of poultry management.

1.3.1.2 Drinking behaviour

Drinking is associated with feed consumption (Savoury, 1978), and increases towards the end of the day at the feeding peak (Wood-Gush, 1959). An adult chicken consumes about 150-200 ml of water per day at normal room temperatures (Appleby et al., 2004). Time spent drinking depends partly upon the type of housing. Bessei (1986) found that hens kept in cages spent about 14% of their time drinking, which was reduced to 6% in covered strawyard (Gibson et al., 1988). Lintern-Moore (1972) also reported that over drinking is more common in birds kept in barren environments.

1.3.1.3 Comfort behaviours

Comfort behaviours such as preening, wing flapping, wing stretching, and body shaking help laying hens keep their plumage in good condition. For example, during preening, preen oil (lipid secretions from preen gland or sebaceous glands; Sandilands et al., 2004) is applied to the whole plumage. The frequency, form, and synchrony of comfort behaviours varies between different housing systems depending on space available, and a lack of space may cause frustration (Nicol, 1987). Sometimes, hens are unable to reach the food target and those hens often engage in activities like preening which leads to frustration as this displaced activity was not expected to occur in the normal circumstances (Duncan, 1970).

1.3.2 Activity behaviours

Performance of basic movements such as walking, running, flying, wing flapping, and wing stretching constitute locomotive behaviours. Hens have been observed to walk up to 1.5 km a day ((Keppler and Fölsch, 2000) and during walking they may be engaged in foraging, running, flying onto perches, playing fighting with each other, and performing dust bathing. The main pattern of resting or sitting and sleeping depends on the photo and scoto periods of the housing systems (Coenen et al., 1988).

1.3.3 Significance of the use of facilities - nests, litter, and perches

It is widely accepted that the barren environment of cages leads to poor welfare of laying hens and that providing them with environmental complexities such as nest boxes, litter, and perches improves their welfare. Therefore, it is important to study the significance and extent of use of nests, litter and perches by different strains kept in floor pens. Laying hens are strongly motivated to use a nest (Smith et al., 1990; Ekstrand and Keeling, 1994) and the absence of nest sites in conventional cages leads to severe frustration of these birds as evidenced by increased gakel calls (Zimmerman et al., 2000), reduced sitting (Meijsser and Hughes, 1989), stereotypical pacing (Sherwin and Nicol, 1993; Yue and Duncan, 2003), and excessive feeding (Meijsser and Hughes, 1989) or preening (Duncan and Wood-Gush, 1972). Because nesting behaviour is controlled by hormonal secretions (Petherick and Rushen, 1997), even in the absence of a nest site this behaviour does not disappear (Wood-Gush, 1982).

Provision of litter in non-cage systems facilitates foraging i.e. pecking and scratching, and dust bathing (Appleby et al., 1993). Foraging is a behavioural need and a behavioural priority as even laying hens housed with wired-caged floors perform scratching behaviour while feeding (Weeks and Nicol, 2006). Dawkins (1989) observed that semi-wild Red Jungle fowl spend around 60% of their time foraging. However in modern hybrid strains this time is reduced

(Schutz and Jensen 2001). Dust bathing in domestic hens is a highly motivated behaviour (Lindberg and Nicol, 1997) that has physical and behavioural effects (Appleby and Hughes, 1991), which contribute to the welfare of laying hens (Appleby et al., 1993). There are three stages of dust bathing: tossing, rubbing, and shaking (Vestergaard 1982; van Liere et al. 1990). Hens perform dust bathing at regular intervals and dust bathing maintains the amount and quality of the feather lipids thus benefiting the plumage condition (van Liere et al., 1990). Mature hens spend on average approximately 0.5 h dust bathing daily (Vestergaard, 1982). Some state that on an average a hen dust bathes every second day (Vestergaard, 1982; van Liere and Bokma, 1987). In the absence of litter hens develop sham or vacuum dust bathing behaviour in which the hen goes through the motions of dust bathing on a bare floor (Baxter, 1994). Some researchers have considered sham dustbathing to be a welfare problem (Vestergaard, 1982) whereas others have suggested it as satisfactory (van Liere, 1992). However, Olsson et al. (2002) reported that sham dustbathing does not satisfy a hen's perception to dust bathe and observed that hens continued to dust bathe when given access to litter even if they had recently performed sham dustbathing. Studies have shown that exposure to a substrate in early life affects a hen's later experience (Nicol et al., 2001).

Perching could be a behavioural priority and also a need as reported by Bubier (1996) who found that there was no difference in the time spent accessing feed, nests, perches, and woodchips even when a cost of a small squeeze gap was imposed. In contrast, Olsson and Keeling (2000) reported that hens did not make any effort to access a perch when another bird was already on it. However, there are reports of 100% perch usage at night when they are provided (Appleby et al., 1993; Olsson and Keeling, 2000). Perches may also improve bone condition and reduce the risk of feather pecking, cannibalism, and aggression (Gunnarsson et al., 1999; Huber-Eicher and Audige, 1999; Cordiner and Savory, 2001; Odén et al., 2002). It is important to ensure that perches are spaced adequately so that birds on lower perches cannot peck the vents of birds above (Wechsler and Huber-Eicher, 1998). The use of wooden perches can improve the footpad condition (Burger and Arscott, 1984).

1.3.4 Gentle (non-aggressive) and aggressive feather pecking

Non-aggressive feather pecking (Keeling, 1995) causes damage to feathers and sometimes pulling the feathers of companion birds (Hughes, 1984). Aggressive feather pecking occurs when birds cause damage to the skin and other parts of the bodies of other birds (Heywang and Morgan, 1944). Non-aggressive feather pecking can also sometimes leads to cannibalism (Cain et al., 1984). Feather pecking has a genetic origin (Hughes and Duncan, 1972; Kuo et al., 1991). Some authors have described an effect of different foraging materials on feather pecking (Blokhuis, 1986; Johnsen and Vestergaard, 1996). Other studies suggested that non-aggressive feather pecking is the redirection of ground pecking in the absence of good quality substrate (Blokhuis and Arkes, 1984). However, Bessei et al. (1984a) reported that the incidence of feather pecking in cages is higher than in floor pens.

1.4 Physical health

The birds' plumage condition and health traits such as bumble foot syndrome, keel bone deformity, and claw length are also influenced by management practices and genotype (Abrahamsson and Tauson, 1995).

1.4.1 Feather condition

Recording of feather condition can be an additional parameter to the behaviour to assess the welfare of laying hens (Moniard et al., 1998). Various scoring systems have been developed for the evaluation of feather condition of laying hens (Hughes and Duncan, 1972; Allen and

Perry, 1975; Tauson et al., 1984). Different strains have different tendencies for feather pecking (Hughes and Duncan, 1972; Cuthbertson, 1980; Bessei, 1984b; Abrahamsson and Tauson, 1995) and there may be a relationship between feather pecking, feather condition, and body weight (Leonard et al., 1995; Tauson and Svensson, 1980). Hughes and Duncan (1972) found that fully feathered or unpecked birds weighed more than pecked birds.

1.4.2 Claw length

Long claws in caged hens can lead to poor welfare. Claws of birds in cages grow excessively and can be injurious to other birds or to the handlers (Glatz, 2002). In recognition of this problem, the European Union has passed a directive that cages shall be fitted with suitable claw shortening devices (Vits et al., 2005). Birds kept on litter floors have shorter claws because they have the opportunity to scratch. Glatz (2002) reported that claws can grow upto 30 mm per year and the middle claw length of modern strains can measure from 18 mm to more than 30 mm by end of the laying period in cages.

1.4.3 Keel bone deformity

Osteoporosis in laying hens makes bones more vulnerable to increased incidence of fractures at various skeletal sites by the end of the laying period (Whitehead and Flemming, 2000). Gregory and Devine (1999) reported that in modern hybrid laying hens, the low breast muscle mass makes keel bones more prone to fractures. Keel bone deformity is a long-standing problem and has been classified as a hereditary disease (Warren, 1937) that is the result of hypocalcification (Buckner et al., 1946). More recently, it is considered as an external problem rather than a developmental defect. Housing systems have a great influence on keel bone fractures/ deformities and incidences are higher in extensive systems than intensive systems (Gregory et al., 1994) because of the increased activity in these systems (Knowles and Broom, 1990). However, keel bone deformities can also occur in conventional cages (Fleming et al., 2004). Fleming et al. (2004) suggested that hens with keel bone deformities have weak bones and fracture incidences might be higher when birds are exposed to increased activities in the extensive systems. Genetic selection could help to resolve this problem.

1.4.4 Footpad dermatitis

Footpad dermatitis is a painful condition and an important welfare problem (Bradshaw et al., 2002). This condition ranges from mild hyperkeratosis (in cages, Abrahamsson et al., 1996) to ulcers of the footpad (in floor pens, Wang et al., 1998), which arise as a result of trauma to the tissues, and are aggravated by contact with contaminated surfaces.

Although alternative housing systems are considered to provide superior bird welfare, this condition is more severe in these than in cage systems. In contrast to these findings, some studies have shown that hens reared in wire cages had poorer foot condition than those reared in floor pens (Simonsen et al., 1980), but the use of plastic cage flooring reduces the incidence of footpad dermatitis (Burger and Arscott, 1984). In floor pens, the use of perches, in combination with poor litter quality is the main cause of footpad dermatitis (Wang et al., 1998) whereas in cages, hyperkeratosis may be caused by the pressure load on footpads while standing on the wire floor (Weitzenbürger et al., 2005).

1.6 Objectives of the current study

Welfare groups, animal rights activists and the public has criticized the conventional cage system of laying hens for their barren environment thereby has given a way to alternative poultry production systems including free run system (Taylor and Hurnik, 1996). Alternative production systems are thought to alleviate these constraints (McLean et al., 1986). However, in these alternative production systems, some concerns like productivity and birds' health must also be addressed. Consensus on these issues is yet to emerge and therefore investigation of the effect of changing from conventional cages to alternative production systems on different welfare indicators requires investigation, especially in relation to the ability of different strains of chickens to adapt to these alternate systems. Genotype is known to be a determinant of how well birds adapt to particular housing systems (Leyendecker et al., 2001). In this study, four strains of laying hens kept in conventional cages and floor pens were studied in order to assess their productivity and welfare by quantifying three parameters: production, behaviour, and physical condition. The specific aims were to compare four strains of laying hens kept in conventional cages and floor pens for:

- Production and egg quality (external and internal). Also, we wanted to compare the bacterial shell contamination for eggs from cages and that for eggs from nest boxes and floor in floor pens.
- Behavioural responses and physical health.
- The use of environmental complexities such as perches and nest boxes in floor pens.

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CHAPTER 2. PRODUCTION AND EGG QUALITY OF FOUR STRAINS OF LAYING HENS KEPT IN CONVENTIONAL CAGES AND FLOOR PENS[1]

2.1 Introduction

Rapid intensification of the poultry industry during the 1930s and 40s has resulted in mechanization and large-scale egg production in laying cages. Keeping hens in cages has permitted a dramatic reduction in labour requirements and improved both barn hygiene and the health of the laying hens. However, this housing regime has been criticized (Brambell, 1965) for providing a barren environment to the birds. This criticism and a growing demand by consumers for eggs from birds not kept in cages (Savory, 2004) has led to the development of alternative and "animal friendly" production systems (real or perceived) including free run housing. However, negative aspects of some of these alternative systems in comparison with the conventional cage system, such as higher ammonia emissions (Groot Koerkamp, 1998), greater labour costs, and unhealthy working conditions (van Horne, 1994) are now coming under scrutiny.

Alternative housing systems for laying hens must be designed to balance the health and the welfare of the birds with consumer preferences, the needs of the industry, and the impact on environment. Different housing systems for laying hens have considerable effects on production traits such as egg weight, feed efficiency, daily feed consumption and mortality (Taylor and Hurnik, 1996; van Horne, 1996; Süto et al., 1997). Egg quality is important for consumer appeal and the economic success of a producer depends on the total number of eggs sold. Egg quality encompasses a number of aspects (Stadelman, 1977) related to the shell (external quality) and to

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the albumen and yolk (internal quality). Egg quality has a genetic basis and the parameters of egg quality vary between strains of hens (Pandey et al., 1986; Silversides et al., 2006). However, egg quality is also influenced by the housing regime under which the hens are kept (Mench et al., 1986; Fraser and Bain, 1994; Vits et al., 2005) as well as by the age of the laying hens (Silversides et al., 2006).

The absence of nest sites in conventional cages has been considered to be the most serious welfare problem (Duncan, 1992) and several experiments have shown that hens are strongly motivated to use a nest (Smith et al., 1990; Ekstrand and Keeling, 1994). Nests are important both due to the birds' preference for them and to the birds' frustration when they are absent (Ekstrand and Keeling, 1994). Notwithstanding the hens' preference for laying eggs in a nest box (Reed, 1994), in free run systems, some hens will still lay their eggs on the floor, and these floor eggs have been considered to be one of the major disadvantages of non-cage systems. Regardless of the housing regimen, bacterial contamination of eggs has also to be taken into consideration (Mayes and Takeballi, 1983; Wall et al., 2008).

This study was undertaken to evaluate the differences in production and internal and external egg quality for four strains of laying hens kept in conventional cages and floor pens.

2.2 Materials and methods

Day-old Lohmann White (LW), Lohmann Brown (LB), and H & N White (HN) chicks were obtained from a commercial hatchery (Pacific Pride Chicks, Abbotsford, BC, Canada) and the chicks from a cross of Rhode Island Red males to Barred Plymouth Rock females (Cross, Silversides et al., 2007) were produced at Agassiz Research Centre. Approximately 120 chicks of each strain were reared in either conventional pullet rearing cages or in floor pens, although fewer Cross chicks were available at hatching. Commercially obtained chicks were beak trimmed at the hatchery and the Cross chicks were beak trimmed at the Agassiz Research Centre. All chicks were wing banded at Day 1.

For the conventional cage treatment, chicks were reared with 60 birds per cage (200 cm^2/bird) until wk 5 and 30 birds per cage from wk 6 to 18 (400 cm^2/bird). At 18 wk of age, a total of 450 birds were distributed randomly with three birds of the same strain per cage (688 cm^2/bird). In floor pens, each strain was reared separately in a single pen until seven wk of age when a total of 432 birds was randomly distributed between pens with 21 to 24 birds of the same strain per pen (6,115 to 6,990 cm^2/bird). Each pen included a 2-tier (50 and 100 cm from the floor) perch assembly and a nest box. Perches were 3×4 cm, were made of soft wood with rounded edges, and provided a space of 18 to 21 cm/ bird. Four-nest, two-tiered nest boxes (Kuhl Corporation, Flemington, New Jersey) provided one nest for each five to six birds. Each nest box was hung on the rear wall of the pen with the nest box rails at 70 and 100 cm from the floor. The birds were exposed to both perches and nest boxes from the second wk of age. In both environments birds were fed manually and water was provided through nipple drinkers. Nutrient content of the feed (Table 2.1) followed recommendations of the National Research Council (1994) and management guides (ISA, 2000). All birds were reared with 9 h of light per day, which was increased to 14 h at 18 Wk with an intensity of 5 lux throughout. Temperature and humidity were between 21 and 23°C and 70%, respectively. All birds were vaccinated following a program typical of the region and birds reared on the floor were also vaccinated against coccidiosis. All procedures were approved by the Animal Care Committee of the Agassiz Research Centre and followed guidelines described by the Canadian Council of Animal Care (1993).

Egg production per cage or pen was recorded for five days per wk and extrapolated to seven days. All eggs were weighed on one day per wk and egg mass was calculated from egg production and egg weight. Feed consumption was measured for one wk at 10-week intervals from 20 to 50 wk of age. Feed efficiency was calculated by dividing the feed consumption by the egg mass produced during the time that feed consumption was measured. Individual BW was recorded every 10 wk starting at Wk 20. Quality of all eggs produced on one day was measured at each of 20, 30, 40, and 50 wk of age. Eggs were stored at 4°C overnight, then broken onto a level surface. The height of the albumen was determined using a standard tripod micrometer after which the yolk was weighed. Shells were washed under running water, dried, and weighed. The albumen weight was calculated by difference. Yolk color was measured with a Roche yolk color fan scale (Roche scale). Mortality was recorded in both regimes over the rearing and laying periods. In floor pens, the location of eggs was recorded for four consecutive days at four wk intervals between 20 and 50 wk of age.

To measure bacterial shell contamination, eggs were collected from the conventional cages (20 eggs) and from the nest-boxes (12 to 20 eggs) and from the floor (12 to 20 eggs) of the floor pens at 38 and 42 wk of age. The eggs were collected into sterile plastic zip lock bags in sterile conditions. Eggs were washed for one minute in the same bags using buffered peptone water (EMD Chemicals Inc., Darmstadt, Germany) with 0.5 ml for each egg. The water was transferred and used for serial dilutions. One ml of each sample was spread on Petrifilms™ (3M, St. Paul, Minnesota) specific for the recovery of *Escherichia coli* and *Coliform* bacteria, incubated at 50°C for 48 hrs, and read at 24 h with verification at 48 h.

Statistical analyses were performed with ANOVA, using PROC GLM procedures of SAS (Version 9.1, SAS Institute Inc., Cary, NC). The model used for most data included the effects of environment, strain, age, and the interactions between them. Data on bacterial shell contamination were subjected to log transformation and analsyzed with an ANOVA including the main effects of source of the eggs, strain, and age and all interactions. Duncan's multiple range tests was used to separate group means. For mortality, a contingency chi-square test was performed to compare mortality among strains and between housing systems. A P value < 0.05 was considered significant for all analyses.

2.3 Results

At Wk 20 to 30, a two-way interaction for environment and strain was significant for hen-day egg production (Tables 2.2, 2.4). In cages, commercial strains (LW, LB, and HN) produced more eggs than the Cross strain. In floor pens, LB and LW hens produced the most eggs and HN hens produced the fewest.

At 20 wk, BW of hens in floor pens was significantly greater than that of hens in cages (Table 2.3). The BW of the hens increased with age to 40 wk, but by 50 wk, hens in cages lost weight and those in floor pens did not. In a full ANOVA, a two-way interaction between environment and strain was significant for BW at Wk 30, 40, and 50 and is described in Table 2.4. In both environments, Brown-egg layers (LB and Cross) were heavier than White-egg layers (LW and HN), with Cross hens being heaviest and HN hens weighing the least. In cages, BW of White-egg layers was not different, but in floor pens LW hens were heavier than HN hens.

There was no significant interaction between environment and strain for feed consumption or feed efficiency (Table 2.3) and this interaction was dropped from the ANOVA. The strain but not the environment influenced the daily feed consumption and feed efficiency. The HN hens ate less than LW, LB, and Cross hens but significantly less than all other strains only at 40 wk. Feed consumption increased from Wk 20 to Wk 40 and feed efficiency was best at Wk 30 and 40. At 30 and 40 wk of age the Cross hens produced eggs significantly less efficiently than LB or either of the White-egg layers.

The strain influenced eggshell weight markedly (Table 2.5). Eggs from LW and LB hens had similar shell weights, which were heavier than those from eggs from HN and Cross hens. A two-way interaction between environment and age for shell weight was significant. In both environments, shell weight increased with age from Wk 20 to 40, but in cages, it decreased at Wk 50 and in floor pens, no significant difference was found at Wk 40 and Wk 50 (data not shown). A significant three-way interaction was found between environment, strain, and age for egg, yolk, and albumen weight, albumen height, and yolk color and another ANOVA was performed (Table 2.6). In both environments, eggs of LB hens were heavier at Wk 20 to Wk 40 than White-egg layers and Cross hens, except at Wk 40 egg weight of HN hens were similar to that of LB hens. At Wk 40, in floor pens, egg weight for Cross hens was not significantly different from that of White-egg layers and LB hens. At Wk 50, egg weight was not significantly different between any strains in either housing system. Yolk weight from Wk 20 to Wk 50 was not significantly different among strains in either environment. At Wk 20, in cages albumen weight was higher for HN hens and in floor pens it was higher for HN hens and Brown-egg layers. At Wk 40, HN and Cross hens in cages had higher albumen weight than LW and LB hens and in floor pens LW hens had lower albumen weight than other strains. In both cages and floor pens, egg weight and shell and yolk weight increased with age.

From Table 2.6 in cages, albumen height of Brown-egg layers was not different between Wk 30 and Wk 40, and that for White-egg layers was not different between Wk 40 and Wk 50. In floor pens, only HN eggs differed significantly between Wk 20 and Wk 30 and had the lowest albumen height at Wk 20 (based on only nine eggs). Albumen height for all strains decreased as the hens' age increased in both environments. Yolk color for all strains in cages was lowest at Wk 30. For White-egg layers there was no difference in yolk color between Wk 40 and Wk 50, whereas for brown egg strains the difference between these ages was significant. In contrast, in floor pens, eggs from Brown-egg layers and HN hens had higher yolk color at Wk 40 and Wk 50 than at Wk 20 and Wk 30. However, LW hens had significantly lower yolk color at Wk 50 than at Wk 40 and the lowest color at Wk 20 and Wk 30.

Mortality during the rearing period in cages was higher for LW hens than for HN hens (Table 2.7). In floor pens, mortality of LB hens was significantly higher than that of LW, HN, and Cross hens. Only LB hens differed in mortality between housing systems. During the laying period, there was no difference among the strains and but mortality was higher in the cages than in floor pens for all but Cross hens.

The LW and HN hens laid 88 and 75% of their eggs in nest boxes, respectively, whereas LB and Cross hens laid 48 and 50% of their eggs, respectively, on the floor, most under the nest box and in the corners near the nest box (Figure 2.1).

No interactions between main effects for bacterial shell contamination were found and they were dropped from the ANOVA (Table 2.8). Eggs from cages had lower *E. coli* and *Coliform* contamination than those from nests and the floor. *E. coli* contamination was higher for LB eggs than LW eggs. No strain difference was found for *Coliform* contamination. Contamination with both bacteria was higher at 42 wk than 38 wk.

2.4 Discussion and conclusions

In this study, egg production of white egg and brown egg commercial hens was similar likely because intensive selection of commercial Brown-egg layers has brought their production to similar levels as those of white egg strains (Scott and Silversides, 2000). Although both parental lines of the Cross hens have very good egg production (Silversides et al., 2007) they have not been selected intensively and a lower level of production than industrial layers could be expected. Early egg production of HN hens was low in floor pens, but not in cages, possibly because maturity was delayed for this strain in this environment.

At 20 wk, birds kept on the floor were heavier than caged birds and they laid larger eggs at least partly because body weights and the egg weights are positively correlated (Siegel 1962). Heavier birds in the floor pens could be attributed to better physical condition (Singh et al., unpublished). Vits et al. (2005) also found higher egg weights in floor pens than in conventional cages, in contrast to the findings of Yakabu et al. (2007) who found that eggs from conventional cages were larger than those from floor pens. Brown-egg layers were heavier and laid larger eggs with higher egg, yolk, and shell weights than White-egg layers, which are in general agreement with Scott and Silversides (2000). In floor pens but not cages, HN hens weighed less than LW hens possibly because HN hens used the increased space more effectively for physical activity.

In this study, we found that shell weights of LW and LB eggs were different from those of HN and Cross eggs, which is not surprising because different strains of laying hens vary significantly in egg shell quality (Curtis et al., 1985). Only minor increases were seen in the shell weight with age in both environments because the hens have difficulty producing an increased amount of eggshell at an older age (Joyner et al., 1987). However, late in production the shells were better in floor pens than in cages likely because increased activity benefits calcium metabolism.

At the start of lay, earlier egg production in cages, especially for HN hens led to heavier eggs. Egg weight is genetically linked to the shell, albumen, and yolk weights although each has different heritabilities. In this study, the major contributing factor to egg weight was the yolk, although the heritability for yolk weight is lower (Washburn, 1979) than those for shell and albumen weights. Basmacioglu and Ergul (2005) also found, higher yolk, shell, and albumen weights in floor pens than that in cages, although Pištěková et al. (2006) found no influence of housing systems on yolk weight.

The housing systems did not influence feed consumption or feed efficiency. The HN hens ate less than LW and Brown-egg layers. Feed efficiency was best for HN hens, possibly because of genetic differences in physical activity, physical condition, basal metabolic rate, body temperature, and body composition (Luiting, 1990). As the hens aged, feed intake increased, with a corresponding increase in BW. Body weights of selected lines of chickens are associated with appetite (McCarthy and Siegel, 1983) and changes in feed intake and feed efficiency that correspond to changes in BW have been clearly demonstrated in other studies (Barbato et al., 1983; Marks, 1991).

Mortality is an important indicator of poor welfare (LayWel, 2006). Higher rearing period mortality in floor pens was because LB hens had very high mortality but no major cause was diagnosed. Higher mortality in cages during the laying period was distributed between the strains. In this study, the mortality for LB hens in cages during the rearing period (less than 3%) and that in floor pens during the laying period (less than 4%) meet the criteria of the Lohmann Brown Management Guide (2005). Tauson et al. (1999) recorded mortality from wk 20 to 80 and found higher mortality of LB hens in floor pens than in cages, largely related to feather pecking or cannibalism, with no difference between housing systems for Lohmann Selected Leghorns (LSL) hens. Abrahamsson and Tauson (1998) also reported higher mortality of LB hens than LSL hens from wk 20 to 80 in a three tiered aviary system due to coccidiosis and feather pecking. We did not find mortality due to feather pecking, cannibalism, or coccidiosis possibly because the birds in this study were beak trimmed and those in floor pens were vaccinated against coccidiosis and perhaps because our groups were homogenous and stable (Estevez et al., 2002, 2003; Dennis et al., 2008).

Lower albumen height in eggs from floor pens than that in cages may partly be due to their exposure to ammonia (from litter), which affects albumen quality (Roberts, 2004). A similar housing effect was found by Süto et al. (1997). Albumen height was greater in white eggs than brown eggs and decreased with age in both environments, similar to the results of Silversides et al. (2006), who studied commercial strains housed in cages. In contrast, Curtis et al. (1985) found better albumen quality in brown eggs than white eggs (using different strains than described here).

Yolk color was higher for eggs from floor pens than for eggs from cages. The main contributing factor for yolk color is the diet (Leeson and Summers, 1991) but although the hens were all fed the same diet in this study, still there was a difference in yolk color between commercial and non-commercial layers. This could possibly be due to the dilution effect of higher egg production by commercial layers and the difference between commercial lines could be attributed to genetic variation that is not related to productivity (Hocking et al., 2003). Differences in the yolk color among strains at different ages could be caused by access to litter in the floor pens. Süto et al. (1997) and Pištěková et al. (2006) both found higher yolk color in floor pens than cages, but provided no reason for the difference.

Nest boxes were provided in the floor pens, but LB and Cross hens used them poorly compared to LW and HN hens, in contrast to studies on nest box usage (Duncan, 1992; Smith et al., 1990; Ekstrand and Keeling, 1994) that found them to be very important for these birds. Reed (1994) and Walker and Hughes (1998) found that design and location of the nest box is important, but our nest boxes were commercially produced and provided two levels at the same level as the perches. Our results show that not all strains are highly motivated to use nest boxes.

Lower bacterial contamination in caged eggs was because the eggs were separated from excreta by the wire floor whereas floor eggs and those from nest boxes were in contact with litter containing excreta. Quarles et al. (1970) also found that eggs from hens kept on litter floors had greater bacterial contamination than those laid in rollaway nest boxes. Eggshell contamination increased with age, likely because litter quality deteriorated with time.

This study found interactions between environments, strains, and ages on hen-day egg production, BW, and egg quality over a period of time, suggesting that the strain should be considered when using alternative housing systems. Our conclusions can only be applied to the four strains and two housing systems studied, but suggest the need for further studies on strain and environment interactions for production and egg quality.

Table 2.1 Major ingredients and nutrients (%) of diets fed to four layer lines in two environments

	1 to 8 Wk	9 to 16 Wk	17 to 20 Wk	21 to 30 Wk	31 to 45 Wk	46 to 60 Wk
Corn	35.60	44.32	45.20	51.82	52.52	54.15
Barley	23.00	21.08	9.98	0	0	0.50
Wheat	10.00	11.00	12.00	8.46	10.30	8.00
Canola meal	13.80	14.00	6.40	4.00	5.00	7.50
Meat meal	2.00	0	0	0	0	0
Soybean meal	10.27	5.06	16.25	21.26	17.79	15.08
Calculated nutrients						
ME, kcal/kg	2800	2800	2800	2800	2800	2800
Crude protein	18.5	15.5	17.0	17.5	16.5	16.0
Calcium	1.00	0.92	2.50	4.10	4.20	4.30

Table 2.2 Egg production of four strains kept in cages and floor pens[1]

Item	Hen day egg production (%)			
	20 to 30 Wk	31 to 45 Wk	46 to 50 Wk	Total
Environment				
Cage	90.8	89.2	72.1^{b}	86.7
Floor pens	81.0	87.3	86.6^{a}	85.0
SEM	0.01	0.01	0.02	0.01
Strain				
LW	93.0	94.3^{a}	71.6^{ba}	89.8^{a}
LB	92.3	88.4^{b}	76.4^{a}	87.5^{a}
HN	89.3	91.9^{ba}	78.4^{a}	88.5^{a}
Cross	82.9	79.2^{c}	66.7^{b}	78.3^{b}
SEM	0.01	0.02	0.02	0.02
ANOVA		*P*		
Environment	<0.01	NS	<0.05	NS
Strain	<0.01	<0.05	<0.05	<0.05
Env*strain	<0.01	NS	NS	NS

[a-c] Means within main effects without a common letter differ ($P < 0.05$).
[1]Total number of observations was 169 for each measurement.

Table 2.3 Body weight, feed intake, and feed conversion of four strains of layers at 20, 30, 40, and 50 Wk of age in cages and floor pens[1]

Item	Body weight (g)				Daily feed intake (g)				Feed efficiency (g of feed:g of egg)			
	20 wk	30 wk	40 wk	50 wk	20 wk	30 wk	40 wk	50 wk	20 wk	30 wk	40 wk	50 wk
Environment												
Cages	1541^{b}	1693	1813	1754	88.7	105.0	111.3	110.3	2.48	2.32	2.09	1.42
Floor pens	1576^{a}	1766	1859	1875	83.4	104.1	111.2	112.2	2.32	1.85	2.01	2.13
SEM	2.3	3.9	4.5	5.0	0.46	0.62	0.69	0.98	0.024	0.046	0.016	0.060
Strain												
LW	1390^{c}	1645	1744	1706	84.9^{b}	102.7^{bc}	112.6^{a}	111.4	2.39	2.04^{b}	2.03^{b}	1.52
LB	1750^{b}	1820	1934	1904	95.6^{a}	109.2^{ba}	114.5^{a}	109.0	2.47	2.17^{b}	2.08^{b}	1.38
HN	1351^{d}	1588	1674	1661	83.6^{b}	97.8^{c}	104.7^{b}	108.1	2.36	1.93^{b}	1.84^{c}	1.66
Cross	1824^{a}	1917	2054	2057	88.3^{b}	111.6^{a}	114.0^{a}	114.4	2.71	3.12^{a}	2.51^{a}	1.48
SEM	1.1	1.98	2.3	2.5	0.23	0.31	0.34	0.34	0.011	0.023	0.008	0.030
ANOVA							*P*					
Environment	<0.01	<0.01	<0.05	<0.01	NS	NS	NS	NS	NS	NS	NS	NS
Strain	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05	NS	NS	<0.01	<0.01	NS
Env*Strain	NS	<0.01	<0.01	<0.01	-	-	-	-	-	-	-	-

[a-d] Means within main effects without a common letter differ ($P < 0.05$).

[1]Total number of observations is 862 for body weight and 169 for feed consumption and 167 for feed efficiency.

Table 2.4 Body weights and hen-day egg production of four strains in cages and floor pens[1]

Strain	Body weight (g)						20 to 30 Wk Hen day egg production (%)	
	30 Wk		40 Wk		50 Wk			
	Cages	Floor pens	Cages	Floor pens	Cages	Floor pens	Cages	Floor pens
LW	1547[c]	1749[b]	1642[c]	1850[b]	1554[c]	1851[b]	93.4[a]	90.4[ba]
LB	1794[b]	1854[a]	1924[b]	1945[a]	1863[b]	1950[a]	91.8[a]	93.2[a]
HN	1542[c]	1632[c]	1638[c]	1708[c]	1570[c]	1741[c]	93.5[a]	54.9[c]
Cross	1952[a]	1879[a]	2116[a]	1987[a]	2101[a]	2012[a]	82.4[b]	86.9[b]
SEM	2.9	2.6	3.4	2.9	3.9	3.1	0.03	0.02

[a-c] Means within main effects without a common letter differ ($P < 0.05$).

[1] Total number of observations for each measurement varied from 394 to 433 for body weight and for hen day egg production was 19 for free run and 150 for cages.

Table 2.5 Egg quality traits of eggs produced by four different strains at Wk 20, 30, 40, and 50 of age in cages and floor pens[1]

Item	Egg weight (g)	Yolk weight (g)	Shell weight (g)	Albumen weight (g)	Albumen height (mm)	Yolk color
Environment						
Cages	54.3^{b}	14.4^{b}	5.21^{b}	34.8^{b}	8.58^{a}	5.05^{b}
Floor pens	58.6^{a}	15.7^{a}	5.49^{a}	37.4^{a}	8.45^{b}	6.11^{a}
SEM	0.14	0.04	0.02	0.14	0.03	0.02
Strain						
LW	55.8^{c}	15.0^{b}	5.44^{a}	35.5^{c}	8.66^{a}	5.41^{c}
LB	56.6^{b}	14.9^{cb}	5.45^{a}	36.3^{b}	8.36^{c}	5.70^{b}
HN	55.0^{d}	14.7^{c}	5.27^{b}	35.1^{c}	8.57^{a}	5.26^{d}
Cross	59.3^{a}	15.8^{a}	5.16^{b}	38.3^{a}	8.46^{b}	6.15^{a}
SEM	0.19	0.06	0.04	0.09	0.04	0.03
Age						
Wk 20	45.0^{d}	9.6^{d}	4.38^{d}	31.1^{c}	9.28^{a}	4.89^{c}
Wk 30	57.0^{c}	14.6^{c}	5.36^{c}	37.1^{a}	8.80^{b}	4.79^{c}
Wk 40	58.5^{b}	16.6^{b}	5.70^{a}	36.2^{b}	8.37^{c}	6.31^{a}
Wk 50	60.3^{a}	17.1^{a}	5.51^{b}	37.7^{a}	7.82^{d}	6.10^{b}
SEM	0.19	0.06	0.04	0.09	0.04	0.03
ANOVA				*P*		
Environment	<0.05	NS	NS	<0.05	<0.05	<0.01
Strain	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Age	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Env*strain	NS	<0.05	NS	NS	<0.05	NS
Env*age	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strain*age	<0.01	<0.01	NS	<0.01	<0.01	<0.01
Env*strain*age	<0.05	<0.05	NS	<0.05	<0.05	<0.05

[a-d] Means within main effects without a common letter differ ($P < 0.05$).

[1]Total number of observations for each measurement varied from 2506 to 2515.

Table 2.6 Egg quality traits produced by four different strains at Wk 20, 30, 40, and 50 of age in cages and floor pens[1]

Attribute and age	Cages				Floor pens			
	LW	LB	HN	Cross	LW	LB	HN	Cross
Egg weight (g)								
Wk 20	45.2^{c}	46.7^{b}	44.3^{c}	47.5^{c}	41.3^{c}	43.0^{b}	38.7^{c}	43.9^{c}
Wk 30	55.0^{b}	57.4^{a}	53.1^{b}	59.0^{b}	57.9^{b}	59.4^{a}	55.9^{b}	60.9^{b}
Wk 40	56.3^{b}	57.4^{a}	56.3^{a}	59.1^{b}	58.2^{b}	61.0^{a}	59.2^{a}	62.7^{ba}
Wk 50	58.7^{a}	58.9^{a}	56.0^{a}	64.0^{a}	61.2^{a}	60.8^{a}	60.3^{a}	63.5^{a}
SEM	0.26	0.29	0.26	0.35	0.27	0.25	0.29	0.36
Yolk weight (g)								
Wk 20	9.60^{d}	9.99^{d}	9.48^{d}	9.73^{d}	8.75^{c}	9.35^{c}	9.22^{c}	9.21^{c}
Wk 30	14.5^{c}	14.7^{c}	13.9^{c}	14.8^{c}	14.7^{b}	15.1^{b}	14.2^{b}	15.2^{b}
Wk 40	16.1^{b}	16.5^{b}	15.6^{b}	17.8^{b}	16.9^{a}	16.5^{a}	16.6^{a}	17.5^{a}
Wk 50	16.8^{a}	17.2^{a}	16.8^{a}	18.4^{a}	17.3^{a}	16.5^{a}	17.0^{a}	17.9^{a}
SEM	0.16	0.17	0.14	0.19	0.13	0.18	0.16	0.19
Albumen weight (g)								
Wk 20	31.1^{c}	32.2^{c}	30.3^{b}	33.5^{c}	28.5^{c}	29.5^{b}	25.6^{b}	30.9^{b}
Wk 30	35.3^{ba}	37.3^{a}	34.1^{a}	39.0^{a}	37.2^{a}	38.6^{a}	36.3^{a}	40.6^{a}
Wk 40	34.2^{b}	35.1^{b}	35.2^{a}	35.6^{a}	35.5^{b}	38.7^{a}	37.7^{a}	40.1^{a}
Wk 50	36.7^{a}	36.6^{ba}	34.1^{a}	40.1^{a}	38.3^{a}	38.4^{a}	37.7^{a}	40.1^{a}
SEM	0.58	0.57	0.52	0.65	0.52	0.48	0.44	0.69
Albumen height (mm)								
Wk 20	9.6^{a}	9.3^{a}	9.4^{a}	9.7^{a}	8.9^{a}	8.7^{a}	7.2^{c}	8.7^{ba}
Wk 30	8.9^{b}	8.3^{b}	8.9^{b}	8.5^{b}	9.1^{a}	8.6^{a}	8.9^{a}	8.9^{a}
Wk 40	8.2^{c}	8.3^{b}	8.3^{c}	8.3^{b}	8.5^{b}	8.3^{b}	8.6^{a}	8.4^{b}
Wk 50	7.9^{c}	7.5^{c}	7.9^{c}	7.7^{c}	7.9^{c}	7.7^{c}	7.9^{b}	7.5^{c}
SEM	0.04	0.05	0.05	0.06	0.04	0.05	0.07	0.06
Yolk color								
Wk 20	4.6^{b}	4.9^{c}	4.7^{b}	5.2^{c}	5.3^{c}	5.3^{b}	5.6^{b}	5.1^{b}
Wk 30	4.1^{c}	4.4^{d}	4.1^{c}	4.4^{d}	5.3^{c}	5.3^{b}	5.2^{b}	5.6^{b}
Wk 40	5.3^{a}	6.2^{a}	5.3^{a}	6.7^{a}	6.7^{a}	7.0^{a}	6.1^{a}	7.8^{a}
Wk 50	5.4^{a}	5.6^{b}	5.2^{a}	5.9^{b}	6.3^{b}	6.9^{a}	6.1^{a}	7.4^{a}
SEM	0.03	0.04	0.03	0.06	0.05	0.05	0.06	0.08

$^{a-d}$ Means within main effects without a common letter differ ($P < 0.05$).

[1]Total number of observations for each measurement varied from 202 to 359.

Table 2.7 Percent mortality of four strains during rearing and laying period in conventional cages and floor pens

Strain	Rearing period		Laying period	
	Cages	Floor pens	Cages	Floor pens
LW	4.32[a]	2.82[a]	10.8[x]	3.33[y]
LB	2.16[ab]	30.5[b,y]	15.8[x]	1.67[y]
HN	0.00[b]	2.16[a]	13.3[x]	5.71[y]
Cross	4.26 [ab]	6.06[a]	7.78	3.45

[a-b] Means within main effects without a common letter differ ($P < 0.05$).
[x-y] Means between main effects of two housing systems without a common letter differ ($P < 0.05$).

Table 2.8 Log 10 count of *Escherichia coli* and *Coliform* microorganisms in caged eggs, nest and floor eggs among four strains during 38 and 42 weeks of age[1]

Item	E.coli	Coli form
Origin of eggs		
Cage	1.89^{b}	1.66^{b}
Nest	4.76^{a}	4.56^{a}
Floor	4.99^{a}	4.39^{a}
SEM	0.26	0.35
Strain		
LW	3.38^{b}	3.04
LB	4.42^{a}	4.19
HN	3.89^{ba}	3.46
Cross	3.82^{ba}	3.45
SEM	0.29	0.41
Age		
Wk 38	3.38^{b}	3.04^{b}
Wk 42	4.46^{a}	4.12^{a}
SEM	0.21	0.29

[1]Total number of observations for each measurement varied from 20 eggs in cages and 12-20 eggs each in nest boxes and floor pens.

[a-b] Means within main effects without a common letter differ ($P < 0.05$).

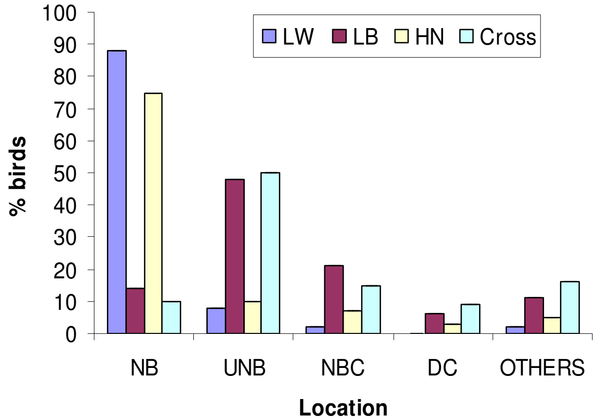

Figure 2.1 Location of eggs laid by four strains in floor pens.

NB: In nest-box; UNB: Under nest box; NBC: Nest box corner; DC: Door Corner.

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CHAPTER 3. COMPARISON OF BEHAVIOUR AND PHYSICAL CONDITION OF FOUR STRAINS OF LAYING HENS IN CONVENTIONAL CAGES AND A FREE RUN SYSTEM[2]

3.1 Introduction

The behavioural repertoire of Red Jungle Fowl has been largely preserved in domesticated chickens (Collias et al., 1966; McBride, 1984) although the frequencies of some behavioural traits have changed significantly during domestication (Craig, 1981). Maintaining poultry welfare in captivity requires finding a balance between genotype and environment that enables the birds to thrive both physically and psychologically while at the same time retaining production characteristics of practical use to the industry. Behavioural responses and measures of physical condition are useful practical indicators for assessing the degree of adaptation of poultry to production environments as they can be monitored rapidly and non-invasively (Mendl, 2001; Newberry et al., 2007).

The change from extensive small scale housing systems to large-scale intensive indoor battery cages approximately 70 years ago brought about a dramatic reduction in labour, ecto- and endoparasitism, and mortality, and allowed higher stocking densities. On the other hand, housing in cages increases fear (Jones and Faure, 1981; Wall, H. 2003), stereotypical behaviour (Craig and Swanson, 1994; Mignon-Grasteau, 2002), and bone weakness (McLean et al., 1986; Jendral et al., 2008), and restricts or prevents the performance of some behaviours in the behavioural repertoire (Koelkebeck and Cain, 1984; Tauson, 1986; Shimmura et al., 2007). More recently, a variety of alternative housing systems for laying hens have been developed in

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response to consumers' concerns for hen welfare. These large-scale systems for poultry production may contribute to sustainable agriculture by boosting farm income through niche marketing of free run eggs (also referred to as barn eggs) while protecting the environment and addressing consumer concerns. Providing more space and offering environmental complexities in alternative systems allows hens to express use of their behavioural repertoire (McLean et al., 1986; Appleby and Hughes, 1991; Michel et al., 2007) and improves some aspects of the physical health of hens (Rönchen et al., 2007) when compared to conventional cages. However these advantages must be balanced against higher potential risks for elevated levels of ammonia (Groot Koerkamp, 1995), cannibalism (Newberry, 2004), greater labour costs, and unhealthy working conditions (Michel et al., 2007).

Choosing the right genotype for the housing type may reduce some of these risks, given that there can be great differences in behavioural profiles between commercial layer strains (Anderson et al., 2004). Selection against harmful behaviours such as cannibalism and feather pecking can improve laying hen adaptation to the social environment, thereby improving hen well-being (Hughes and Duncan, 1972; Cuthbertson, 1980; Bessei, 1984; Craig, 1992; Abrahamsson and Tauson, 1995; Craig and Muir, 1998). Feather condition and health traits such as bumble foot syndrome, keel bone deformity and claw length are also influenced by genotype (Abrahamsson et al., 1996). In addition, genetic predispositions may be expressed differently in different housing environments, resulting in more severe welfare problems in one system than another (Leyendecker et al., 2001; Wall, 2003; Newberry, 2004) depending on genotype. For example, the severity of footpad dermatitis may vary between housing types depending on genetic predisposition to use perches (Abrahamsson et al., 1996).

Considering the growing market for cage-free eggs, there is a need for replicated experiments evaluating the relative adaptability of different breeds to different housing types. The objectives of this study were to determine the effects of conventional cage and free run (floor pen) housing systems on behavioural profiles and physical condition of four strains of laying hens.

3.2 Materials and methods

3.2.1 Birds and housing

One-day-old beak trimmed female chicks of three strains, Lohmann White (LW), H & N White (HN), and Lohmann Brown (LB), were obtained from a commercial hatchery (Pacific Pride Chicks, Abbotsford, BC, Canada). Their beaks were trimmed by laser beak trimming at the hatchery. Chicks from a Cross of Rhode Island Red males and Barred Plymouth Rock females (described by Silversides et al., 2007) were produced at the Agassiz Research Centre, where their beaks were trimmed using a cauterizing blade at one day of age. All birds were provided nine hours of light per day during rearing, and 14 hours from 18 weeks of age onwards. Light intensity was 5 lux for all birds throughout the trial. A temperature of 21 to 23°C and a humidity of 70% were targeted. All birds were fed manually with a standard starter diet to 4 weeks of age, a grower diet to 18 weeks of age, and a layer diet from 18 weeks of age onwards, and feed and water were provided to allow ad libitum consumption (Singh et al., "In Press").

Caged birds were reared in pullet cages with 60 birds/cage (200 cm^2/ bird) until week five and 30 birds/cage (400 cm^2/bird) from weeks 6 to 18. At 18 weeks, a total of 450 birds were randomly assigned to adult laying cages with three birds/cage (688 cm^2/ bird). Adult cages (50.8 cm long, 40.64 cm wide, 45.72 cm deep, 40.64 cm high at the front, with a nine degree floor slope (Custom design and manufactured by Ford Dickinson in Ontario) were arranged on two tiers in a single row with two sides, and each side had 80 cages. The floors and sides of the cages were made of 2.5 × 5 cm wire mesh. The bars on the doors were horizontal and doors covered the entire width and height of the cage. Each cage was provided with a feed trough along the front and two nipple drinkers at the back, with shared access to the drinkers between birds in adjacent cages. The cage floors did not provide any claw shortening coating. Excreta were collected on a manure belt running under the cages of each tier.

Floor birds were reared in four floor pens with each strain separate until seven weeks of age when a total of 432 birds were distributed randomly in four or five pens per strain with 21 to 24 birds/pen (6,115- 6,990 cm^2/ bird). Each pen was 515 cm long, 254 cm wide and 285 cm high. Wood shavings were used as litter (10 cm deep). Each pen was provided with ten nipple drinkers and two tube feeders arranged opposite each other along the length of the pen. Pens included a two-tier vertical perch assembly and a nest box unit, which were provided from the second week of age. Perches were made of 3 cm x 4 cm softwood, and had rounded edges. The two tiers were positioned 50 and 100 cm above the floor, and provided 18 to 21 cm of perching space per bird. Four-hole metal nest boxes (Kuhl Corporation, Flemington, NJ, USA) measured 60 cm wide x 30 cm deep x 86 cm high, and provided one nest for each five to six birds. In each pen, the nest box was hung on the rear wall, with the nest box rails at 70 and 100 cm from the floor. In addition to the standard ration, floor birds were fed 200 g/pen of whole wheat three days per week on alternate days from seven weeks of age onwards.

All birds were vaccinated in accordance with a standard vaccination schedule for the region, and floor birds received an additional coccidiosis vaccine at Day 1. All procedures were approved by the Animal Care Committee of the Agassiz Research Centre and followed guidelines established by the Canadian Council of Animal Care (1993).

3.2.2 Behavioural observations

Behavioural observations of birds in each pen or cage were made at 22, 35, and 42 weeks of age. Instantaneous scan sampling was used to assess the time spent performing different behaviours while continuous focal sampling was used to measure the frequency of behavioural events (Martin and Bateson, 1993). One cage or pen/ strain was observed on each of the two observation days at each age, during four 30-min time blocks, two in the morning between 9:00 and 10:15 AM, and two in the afternoon between 1:00 and 2:15 PM. These observations were carried out by two observers who sat in front of the cage or pen with the first five minutes used for adaptation of hens to their presence. After the adaptation period, one observer conducted five min of instantaneous scan sampling successively in each of five functional areas within a pen or within each cages. Floor pens were divided into four equal areas by plastic strings, with a fifth area that included the nest box, creating the five observation areas per pen. During each 5-min period, instantaneous scan samples of behaviour were performed each minute on all hens present within an observation plot or cage (see Table 3.1 for ethogram). Simultaneously, the second observer conducted focal sampling continuously for 25 min on one randomly selected bird per pen or cage (Table 3.1). For focal sampling, two hens per floor pen or cage were chosen at random and marked at least a week before with yellow non-toxic gouache liquid (Schola®, Marieville, Quebec, Canada). If the marked hen disappeared from sight during an observation, the second marked hen was observed for the remaining time.

Cages and pens were observed in a random order. Two replicates of each strain in cages or floor pens were observed on alternative days for four days. Scan sampling data from each functional area per pen or each cage were added and the percentage of hens performing each behaviour per 25-min observation session was calculated. For continuous focal sampling, data were summed to give the frequency of each behaviour (Table 3.2) performed per hen per 25-min period.

The use of perches by hens in floor pens was observed at 27 to 28 weeks of age for four consecutive days. Ten min prior to the lights going off, the hens on perches, on the floor, and perched under the roof, on drinkers or inside the nest box were counted.

3.2.3 Physical condition of birds

Birds in each housing system were observed for feather condition, claw length (in mm, middle toe of the right foot), foot condition and keel bone deformity at weeks 20 and 50 (Table3. 2). One bird from each cage and eight birds per pen were randomly selected for assessment. Feather condition was assessed using a five point scoring system (Abrahamsson et al., 1996) for seven different areas of the body (head, neck, back, wings, tail, abdomen, and breast). At the same time, both feet of each bird were assessed for lesions (Nicol et al., 2006) and keel bone deformity (Elson and Croxall, 2006) was observed, both using a five point scoring system.

3.2.4 Statistical analyses

Percentage of time spent on different behaviours from scan sampling was transformed using arcsine (square root) and the frequency of different behaviours from focal sampling and most physical condition data was transformed to square root transformations before analysis. Statistical analysis was performed on all transformed behaviour data using PROC GLM of SAS (Version 9.1, SAS Institute Inc., Cary, NC, USA). The model used for behaviours included the fixed effects of environment (2), strain (4), age (3) and time (2), and interactions between them. Preening, dust bathing, wing flapping, tail wagging, and body shaking (considered comfort behaviours) occurred in floor pens only and the model was reduced appropriately. Non-significant interactions were removed from the model. Repeated measure design was not used in this experiment because different birds were observed during each age and or time. For perch use, PROC MIXED of SAS was performed with day as a random effect and strain as a fixed effect. For ease of analysis, data on the presence of birds under the roof, on the drinkers, and on or in the nest box were combined into 'other'. All transformed data for claw length, feather score, and keel bone deformity were analysed using PROC GLM of SAS. Foot condition score for birds in the floor pens was analysed using the Chi-square contingency test. All birds in cages had a foot condition score of one). The model used for physical condition included the effect of environment and strain and the interactions between them. Group means were separated by Duncan multiple range tests. A P value < 0.05 was considered to be significant.

3.3 Results

3.3.1 Behaviour

Behaviour measured by instantaneous scan sampling is shown in Table 3.3. Time spent eating was not affected by any of the main effects or their interactions. The main effects of environment ($P<0.01$) and strain ($P<0.05$) were significant for time spent drinking (Table 3.3). Caged hens spent the most time drinking than hens in floor pens and LW hens spent the most time drinking and LB hens spent the least. Hens spent more time sitting in the morning than in the afternoon, but they spent more time foraging in the afternoon ($P<0.05$). Perches were rarely used during the day, when White-egg layers spent more time on perches than the Brown-egg layers (Table 3.3).

From scan sampling data in a full ANOVA, 3-way interactions between environment, strain, and age were significant for standing and walking and are described in Table 3.4. No significant differences were found between strains and age for standing and walking in either environment but birds in cages spent much more time standing than those in pens (Table 3.3). In cages, no significant difference was found for walking between strains but an interaction was found between strain and age, which is shown in Table 3.5. There was no significant difference among strains at 22 and 42 weeks of age, but at week 35, Cross and LW hens spent the most time walking although LW and LB hens were not different, nor were LB and HN hens.

In the ANOVA for preening, dust bathing, and tail wagging, the effect of strain was not significant but age was significant for tail wagging and time was significant for preening and dust bathing (Table 3.3). Birds spent time more time preening and dust bathing in the morning than in the afternoon. Birds spent most time tail wagging at Wk 22 which decreased with age. No effect was significant for wing flapping and body shaking.

Data from focal sampling showed that strain had a significant effect (P<0.05) on gentle feather pecking (Table 3.8) which was more frequent in Brown-egg layers (LB, Cross) than in White-egg layers (LW, HN). Two-way interactions between environment and time and environment and age for feather pecking were significant (P< 0.01) and are described in Tables 3.6. In cages, frequency of gentle feather pecking was higher in the afternoon than in the morning but in floor pens, the frequency was higher in the morning (Table 3.6). In cages, gentle feather pecking increased with age (Table 3.6) but in floor pens, it decreased with age. A 3-way interaction for pecking at the enclosure was found between environment, strain, and age (Table 3.7) and is further described in Table 3.4. Very little pecking at the enclosure was seen in floor pens but in cages, the 2-way interaction between strain and age was significant and is described in Table 3.5. No peck the enclosure was seen for LW hens at 42 weeks and for Cross hens at 22 weeks of age, and no significant differences were found between strains and ages. None of the main effects or interactions was significant for aggressive behaviour.

Results from use of perches just before dark are shown in Figure 3.1. Most hens of the white-egg strains, LW (76%) and HN (65%), used the perches, in contrast to low perch use by hens of the brown-egg strains, LB (7%) and Cross (9%). Most of the LB (92%) and Cross (91%) hens were found on the floor at this time.

3.3.2 Physical health

At 20 weeks all birds had full feather cover, no bad feet and no keel bone deformity in either housing system and these data are not shown. In a full ANOVA, an interaction between environment and strain for claw length was significant (P<0.05) at 20 and 50 weeks (Table 3.8) and is shown in Table 3.10. In cages, claw length of LB at 20 week was significantly shorter than that for LW, HN, and Cross hens but in floor pens White-egg layers had longer claws than the Brown-egg layers.

At 50 weeks of age (Table 3.9), Cross hens in floor pens had significantly higher foot condition score than LW hens, with scores for HN and LB hens not being significantly different from those of any other strain. Two-way interactions were found to be significant ($P<0.01$) between environment and strain for feather condition, keel bone deformity, and claw length (Table 3.8) and are described in Table 3.9. In cages, Cross hens had the highest feather score, HN hens had intermediate score, and LB hens had the lowest score, with that for LW hens not significantly different from Cross and HN hens. In floor pens, LB also had the lowest feather score but LW, HN, and Cross hens were not significantly different from each other. In cages, White-egg layers had higher keel bone deformity score than the Brown-egg layers, but in floor pens, Cross hens had higher keel bone deformity scores than LW, LB, and HN hens, which were not different from one another. At 50 weeks, claw length in cages was greater for White-egg layers than for LB hens but Cross hens were not significantly different from any other line. In floor pens, White-egg layers had significantly greater claw length than the Brown-egg layers.

3.4 Discussion and conclusions

Cages have been criticized for restricting the expression of natural behaviours of chickens. This expression is known to be influenced by genetics (Leyendecker et al., 2001) making it relevant to compare behaviours of different strains kept in alternative housing systems. In this study, four strains of laying hens kept in two housing systems were studied to assess hen welfare by observing behaviour and physical condition.

More time spent drinking by the caged hens could be attributed to the greater time spent eating (although not significant) in cages because drinking and feeding are positively correlated (Carmichael et al., 1999). Alternately, the hens may play with their water out of boredom, an observation that has been described in pigs maintained in barren environments (Terlouw et al., 1991; Terlouw et al., 1991a, b). Our results agree with the findings of Bessei (1986) who found that caged hens spent 14% of their time drinking and Gibson (1988) who found that hens on the floor spent only 6% of their time drinking. Strain differences in time spent drinking could be due to strain differences in feed consumption (non-significant) or adaptation to a barren environment. Hens spent more time sitting (in both environments) and preening and dust bathing (in floor pens) in the morning and foraged more in the afternoon, indicating increased activity in the afternoon. These results agree with those of Carmichael et al. (1999) who observed the behaviour of ISA Brown hens in a perchery system at different stocking densities.

Daytime observations indicated that White-egg layers used perches more than Brown-egg layers. However, in contrast to the findings of Newberry et al. (2001) for younger pullets of a White Leghorn strain, use of perches was low when our observations were made. Based on observations just prior to onset of the scotoperiod, it appears that the hens used perches principally for roosting at night, again with limited use by Brown-egg layers. Channing et al. (2001) observed that commercial brown egg layers used perches for resting during the day, and Duncan et al. (1992) reported that a strain of commercial brown egg layers used perches that were added to conventional cages more often than a White Leghorn strain, suggesting that use of perches depends on the specific strains under comparison. In our study, the Brown-egg layers were also heavier than the White-egg layers (Singh et al., in press), which could suggest that perch use is linked to body weight. Olsson and Keeling (2000) observed that a commercial strain of White Leghorns had reduced welfare without perches and that hens were highly motivated to use perches, in agreement with our observations for the White Leghorn strains.

Time spent walking reflects the hens' level of activity. A greater time spent walking by Cross and LW hens in cages might indicate frustration to the cage environment. Caged hens spent most of their time standing and eating, possibly because of the restricted space in cages, whereas on the floor activities were more evenly distributed. The complete absence of preening, wing flapping, tail wagging, and body shaking in cages might not relate to the space available (Hardie and Dawkins, 1989) but might be because these behaviours did not occur when the observations were made.

Gentle feather pecking was performed more frequently in cages than in floor pens. This could be related to the preening level as more feathers were out of place. It could also relate to the absence of a litter substrate for foraging and dust bathing (Abrahamsson et al., 1996), resulting in redirection of foraging (Blokhuis and Arkes, 1984). A higher frequency of gentle feather pecking in the afternoon in cages could be related to the hens' motivation for foraging at that time and the absence of foraging material in cages. In cages, higher frequency of pecking at enclosure could possible be considered as displaced foraging behaviour. However, Duncan (1970) and Duncan and Wood-Gush (1972) found increased cage pecking in their study and indicated that hens in cages are frustrated.

Although aggression has been predicted to be high in floor pens because of the larger group size (Bilčík and Keeling, 1999), aggression may be reduced among adults of modern commercial strains (Cheng and Muir, 2007). Aggressiveness is primarily influenced by the number of birds in the immediate vicinity of a resource and by differential plumage markings (Estevez et al., 2002, 2003; Dennis et al., 2008). Our groups were homogenous and stable which may help to explain why we saw neither environment nor strain effects on overall aggression.

In floor pens, there was no difference in feather condition between the start and end of lay, whereas in cages the feather condition deteriorated over time. Large naked patches at the base of neck and on the breast were likely caused by repeated pressing of these areas against cage wires while feeding rather than by severe feather pecking, which was not observed. Claws were longer in cages than in floor pens, in agreement with the findings of Vits et al. (2005), because no abrasive claw-shortening devices ware used in the cages. In general, alternative housing systems are considered to be more prone to keel bone deformities because of fractures caused by the inappropriate use or design of perches (Scholz et al., 2008.). However, these deformities could also occur in conventional cages without perches because of osteoporosis (Whitehead and Fleming, 2000). In this study, no obvious keel bone fractures were found in either housing system but twisted keel bones, which could be the result of hairline fractures (Flemming et al., 2004), comprised the major proportion of keel deformities and is a welfare problem. These results agree with the findings of Wilkins et al. (2004) who considered them to provide evidence of a serious welfare problem. In contrast, Elson and Croxall (2006) found that twisted keel bones were not harmful to the welfare of hens. Although alternative housing systems are considered to provide superior bird welfare, all birds in cages had good foot condition whereas some of those in floor pens had foot condition scores indicating the presence of a lesion. Wang et al. (1998) also found that better foot condition in cages than floor pens, but reported lesion scores much higher than those found in our study. Cross hens had the worst feet, with intermediate scores for LB and HN hens and low scores for LW hens. Foot lesions may have been related to the use of perches combined with poor litter quality.

Different behaviour patterns for different strains of birds in cages or floor pens may be an indication of their adaptation to these environments (Dawkins, 1990). The welfare indicators used in this study showed that cages restricted the hens' behaviour compared to floor pens, and that the use of environmental complexities was strain specific in floor pens. These findings suggest that the welfare of laying hens in these housing systems is a complex matter involving the genotype and further studies involving different genotypes in alternative housing systems are needed.

Table 3.1 Ethogram

Behaviour[1]	Description
A. Instantaneous scan sampling	
Feeding	Eating from feeder.
Drinking	Drinking from the water-nipple.
Standing	Standing still for more than 3 s or taking fewer than 3 steps before stopping, not preening, wing flapping, wing/leg stretching or body shaking.
Sitting	Sitting with the sternum on the floor, not dust bathing or preening.
Walking	Walking more than 3 steps, no beak contact.
Foraging	Pecking or scratching in litter while in standing posture or stepping forward.
Perching	Birds on perches during daytime. No behaviour was observed while the birds were on perches
Dust bathing	Making vertical wing shakes while sitting, side lying.
Preening	Grooming feathers and other body parts with beak or foot while in standing or sitting posture.
Wing flapping	When in standing posture or stepping forward, the neck is stretched and both wings are raised in the air and lowered more than once.
Body shaking	Shaking the body with the whole body in motion while in standing posture.
Tail wagging	Shaking the tail with the whole body either in motion or while in standing posture.
B. Continuous focal sampling	
Gentle feather peck	Gentle peck at the feathers of another bird, without breaking or removing feathers.
Aggressive behaviour	One or more severe pecks at the head of another bird, fight with another bird.
Peck at enclosure	Peck at the wall or floor or roof of cage/floor pen without scratching wired cage floor or litter in the floor pens.

[1]Within sampling type, behaviours are mutually exclusive.

Table 3.2 Scoring systems of physical condition parameters

Feather scoring	1 Full feather cover, 2 Worn feathers detectable; 3 Small bare patches ≤ 30 mm diameter; 4 Large bare patches with > 30 mm diameter; 5 No feathers over most of the areas of head, neck, back, wings, tail, abdomen, and breast
Foot condition	1 Good condition; 2 Lesions visible but not infected; 3 Severe lesions, small but not widespread; 4 Poor foot condition with wide spread lesions but no signs of bleeding; 5 Very poor foot condition with severe lesions and bleeding
Keel bone deformity	1 Good, 2 No skin lesion but twisted, 3 Large deformity, 4 Bone fracture, 5 Bone fracture with skin lesion

Table 3.3 Time spent (%) performing different behaviours in free run and cages measured by instantaneous scan sampling[1]

Items	Stand	Walk	Eat	Drink	Sit	Forage	Perch	Comfort behaviours				
Environment								Preen	Dust bath	Wing flap	Tail wag	Body shake
Cages	32.5	2.3	25.1	7.0[a]	0.9	-	-	0.0	0.0	0.0[b]	0.0	0.0
Free run	9.6	9.0	17.5	2.2[b]	1.9	31.5	1.7	5.1	0.9	0.1[a]	1.1	0.0
SEM	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Strain												
LW	15.1	5.0	24.3	8.0[a]	1.6	25.2	6.2[a]	0.6[b]	0.2	0.0	0.0	0.0
LB	22.3	4.1	17.5	2.0[c]	0.4	52.0	0.3[b]	2.1[a]	0.3	0.0	0.0	0.0
HN	22.2	3.7	19.0	3.3[bc]	1.0	17.9	4.1[a]	2.1[a]	0.1	0.0	0.0	0.0
Cross	18.3	7.8	24.0	5.1[ba]	3.2	35.7	0.0[b]	0.8[ba]	0.3	0.0	0.1	0.0
SEM	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Age												
Wk 22	16.0	3.6	23.0	3.9	0.7	34.1	1.8	1.3	0.5	0.0	0.2	0.0
Wk 35	21.3	9.0	19.2	5.7	2.4	38.0	1.5	1.2	0.9	0.0	0.0	0.0
Wk 42	21.1	3.4	21.1	3.4	1.3	23.4	1.8	1.5	0.2	0.0	0.0	0.0
SEM	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Time												
AM	5.0	5.8	22.1	3.4	3.5[a]	21.7[b]	2.4	2.2	0.6	0.0	0.0	0.0
PM	15.7	4.4	20.1	5.3	0.3[b]	43.9[a]	1.1	0.7	0.1	0.0	0.0	0.0
SEM	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
ANOVA							*P*					
Env	<0.01	<0.01	NS	<0.01	NS	-	-	<0.01	<0.01	<0.05	<0.05	NS
Strain	NS	NS	NS	<0.05	NS	NS	<0.05	<0.05	NS	NS	NS	NS
Age	NS	<0.05	NS	NS	NS	NS	NS	NS	NS	NS	<0.05	<0.05
Time	NS	NS	NS	NS	<0.05	<0.05	NS	<0.05	<0.05	NS	NS	NS
Env*strain	NS	NS	NS	NS	NS	-	-	NS	NS	NS	NS	NS
Env*age	NS	<0.01	NS	NS	NS	-	-	NS	NS	NS	<0.05	<0.05
Env*time	NS	NS	NS	NS	NS	-	-	<0.05	<0.05	NS	NS	NS
Strain*age	NS	<0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Env*strain*age	<0.05	<0.05	NS	NS	NS	-	-	NS	NS	NS	NS	NS

[1]Total number of observations was 96, except for foraging and perching for which there were 48 observations.
[a-c] Means within each main effect with common superscripts are not different at P <0.05.

Table 3.4 Time spent (%) on standing and walking (instantaneous scan sampling) and peck at enclosure (focal sampling) by four strains of laying hens at different ages in cages and floor pens[1]

Items	Cages			Free run		
	Stand	Walk	Peck at enclosure	Stand	Walk	Peck at enclosure
Strain						
LW	24.8	2.0	0.2	7.9	9.5	0.0
LB	24.3	0.7	0.2	12.9	10.2	0.0
HN	46.8	1.7	0.2	6.7	6.6	0.0
Cross	26.2	5.9	0.2	11.7	10.1	0.0
SEM	0.01	0.00	0.00	0.00	0.00	0.00
Age						
Wk 22	27.5	1.1	0.2	7.7	7.7	0.0
Wk 35	32.8	9.3	0.3	12.2	8.8	0.0
Wk 42	37.6	0.2	0.1	9.3	10.7	0.0
SEM	0.01	0.00	0.00	0.00	0.00	0.00
ANOVA			*P*			
Strain	NS	NS	NS	NS	NS	NS
Age	NS	<0.01	NS	NS	NS	NS
Strain*age	NS	<0.05	<0.05	NS	NS	NS

[1]Total number of observations for each measurement was 48.

Table 3.5 Time spent (%) on walking (instantaneous scan sampling) and frequency of pecking at the enclosure {(n/25min/bird) focal sampling} by four strains of laying hens at different ages in cages[1]

Main effect	Lohmann White	Lohmann Brown	H & N White	Cross	SEM
Walking					
Wk 22	4.0	4.0	4.0	4.0	0.01
Wk 35	16.0[b]	4.0[bc]	4.0[c]	24.0[a]	0.01
Wk 42	1.0	4.0	4.0	4.0	0.01
Peck at enclosure					
Wk 22	0.1	0.1	0.1	0.0	0.02
Wk 35	0.1	0.1	0.1	0.1	0.02
Wk 42	0.0	0.1	0.1	0.1	0.01

[1]Total number of observations for each measurement were 32.
[a-c] Means within a row without common superscripts differ ($P < 0.05$).

Table 3.6 Frequency of gentle feather pecking (n/25 min/bird, focal sampling) at different time intervals and different ages in cages and floor pens[1]

Gentle Feather pecking			
Time	Cages	Floor pens	SEM
Morning	0.04[a]	0.03[b]	0.00
Afternoon	0.05[a]	0.01[b]	0.00
Age			
Week 22	0.03[a]	0.04[a]	0.00
Week 35	0.05[a]	0.01[b]	0.00
Week 42	0.06[a]	0.00[b]	0.00

[1]Total number of observations for each measurement were 32.
[a-b] Means within a row without common superscripts differ ($P < 0.05$).

Table 3.7 Frequency of different behaviours (n/25 min/bird) in cages and floor pens measured by focal sampling[1]

Main effect	Gentle feather peck	Peck at enclosure	Aggressive behaviour
Env[2]			
Cages	4.3	20.6	2.2
Floor pens	1.5	0.2	1.9
SEM	0.00	0.00	0.07
Strain			
LW	1.3[b]	6.5	4.2
LB	4.7[a]	6.2	2.5
HN	1.6[b]	7.3	0.0
Cross	4.2[a]	4.9	5.6
SEM	0.00	0.00	0.04
Age			
Wk 22	3.1	6.2	5.4
Wk 35	2.7	9.1	2.5
Wk 42	2.4	4.2	0.3
SEM	0.00	0.00	0.04
Time			
AM	3.3	5.5	1.3
PM	2.3	6.9	3.0
SEM	0.00	0.00	0.07
ANOVA		*P*	
Env	<0.01	<0.01	NS
Strain	<0.05	NS	NS
Age	NS	<0.05	NS
Time	NS	NS	NS
Env*age	<0.01	<0.05	NS
Env*time	<0.01	NS	NS
Strain*age	NS	<0.05	NS
Env*strain*age	NS	<0.05	NS

[1]Total number of observations for each measurement varied from 87 to 96.
[2]Housing environment.
[a,b] Means within each main effect with common superscripts are not different at $P < 0.05$.

Table 3.8 Physical health of four strains of laying hens at week 50 and Claw length measurement at week 20 and 50 in conventional cages and floor pens[1]

	Week 50		Week 20	Week 50
Items	Feather condition	Keel bone deformity	Claw length	Claw length
Env[2]				
Cages	2.1	1.4	2.0	2.3
Floor pens	1.2	1.3	1.6	1.9
SEM	0.00	0.02	0.00	0.00
Strain				
LW	1.7	1.4	1.9	2.3
LB	1.6	1.0	1.7	1.9
HN	1.6	1.5	1.9	2.3
Cross	1.7	1.3	1.7	1.9
SEM	0.00	0.03	0.00	0.00
ANOVA		*P*		
Env	<0.01	NS	<0.01	<0.01
Strain	<0.01	NS	<0.01	<0.01
Env*strain	<0.01	<0.01	<0.05	<0.01

[1]Total number of observations for each measurement varied from 150 to152.
[2]Housing environment.
[a-b] Means within each main effect with common superscripts are not different at $P < 0.05$.

Table 3.9 Feather condition, keel bone deformity, and claw length of four strains of laying hens at 50 weeks in conventional cages and floor pens and foot condition only in floor pens[1]

	Cages			Floor pens			
Strain	Feather condition	Keel bone deformity	Claw length	Feather condition	Keel bone deformity	Claw length	Foot condition[2]
LW	2.2^{ab}	1.9^{a}	2.3^{a}	1.2^{a}	1.0^{b}	2.3^{a}	0.05^{a}
LB	1.9^{c}	1.0^{b}	2.1^{b}	1.1^{b}	1.0^{b}	1.6^{b}	0.15^{ab}
HN	2.1^{ab}	2.2^{a}	2.3^{a}	1.2^{a}	1.0^{b}	2.2^{a}	0.20^{ab}
Cross	2.4^{a}	0.4^{b}	2.2^{ba}	1.2^{a}	2.5^{a}	1.6^{b}	0.27^{b}
SEM	0.00	0.09	0.00	0.00	0.00	0.00	-

[1]Total number of observations for each measurement varied from 150 to 152, with 96 observations for foot condition in floor pens.

[a-b] Means within a column without common superscripts differ ($P < 0.05$).

[2] Foot condition score in floor pens was analysed using chi square contingency test.

Table 3.10 Claw length at week 20 of four strains of laying hens in conventional cages and floor pens[1]

Items	Cage	Floor pens
Strain		
LW	2.1[a]	1.8[a]
LB	1.9[b]	1.5[b]
HN	2.1[a]	1.8[a]
Cross	2.0[a]	1.5[b]
SEM	0.00	0.00

[1]Total number of observations for each measurement varied from 150 to 152.
[a-c] Means within each main effect with common superscripts are not different at $P < 0.05$.

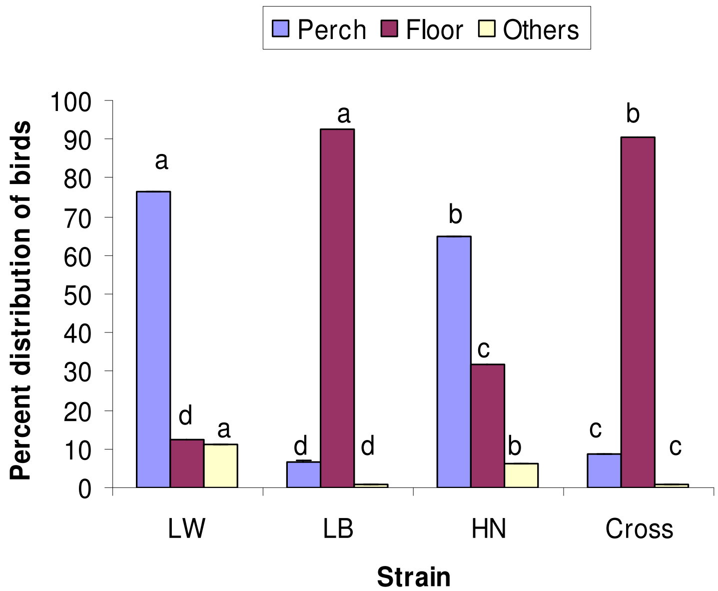

Figure 3.1 Use of perches just prior to lights off by four strains at 27 to 28 weeks of age in floor pens. (LW: Lohmann White; LB: Lohmann Brown; HN: H & N White; Cross: cross)

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CHAPTER 4: OVERALL DISCUSSION AND CONCLUSIONS

Decisions about animal welfare are based on human values and ethics as well as on science. The lives of animals, as of people, may be enhanced by providing comforts beyond those absolutely required to sustain proper biological functioning, and by eliminating unnecessary suffering. If one accepts that the concept of "quality of life" applies to animals as to people one is necessarily presented with a conflict between the demands placed on "production" animals by economics and the demands placed upon the animal keeper by regard for the animals' welfare. How to resolve this conflict is very much a subject of debate. Space is at the centre of this debate. Standards vary from 450 cm^2 to 750 cm^2 per bird in cages (Animal welfare report, 2005) and up to 1845 cm^2 in extensive systems (BCSECP for Free-range and Free-run; BCSPCA-Certified Standards for Raising and Handling of Laying Hens). In this study, a floor space of 688 cm^2/bird was provided in cages and 6,115 to 6,990 cm^2/bird was provided in the free run system. In our free run system more space was provided than recommended to remove the space constraint completely.

It is widely accepted that conventional cages negatively impact hen welfare. "Cage-free" methods of poultry production are said to alleviate these constraints (McLean et al., 1986). However, in these alternative production systems, some concerns like productivity, hen and worker health, labour requirements, and hygiene which were addressed in cages, have started to reappear in alternative housing systems and must be addressed. However, Leyendecker et al. (2001) reported that genotype also plays an important role as a determinant of birds' adaptation to different housing systems. Therefore, production, behaviour, and physical condition of four strains of laying hens kept in conventional cages and floor pens were studied in order to assess their productivity and welfare in these systems.

Birds kept on the floor were heavier than caged birds at 20 wk, and they laid larger eggs. We attributed that, at least in part, to the known high positive correlation between body weight and egg weight (Siegel, 1962). Heavier birds in the floor pens could be attributed to better feather condition (Hughes and Duncan, 1972), supported by the findings of this study that floor birds had better feather cover than caged birds. Vits et al. (2005) also found higher egg weights in floor pens than in conventional cages, in contrast to the findings of Yakabu et al. (2007) who found that eggs from birds kept in conventional cages were larger than those from floor pens. Brown-egg layers were heavier than White-egg layers, which is in general agreement with Scott and Silversides (2000).

Late in the production period eggshells were better for birds in floor pens than those in cages possibly because increased physical activity may benefit calcium metabolism. The strain differences found in this study support the findings of Curtis et al. (1985) who reported that different strains lay eggs with different eggshell quality. Shell weight increased with age but the increment was small and was proportionately less than the increase. The laying hen deposits only a finite amount of calcium in the shell and with the increase in egg size with increasing age, a similar amount of calcium has to be spread over a larger surface (Joyner et al., 1987).

Eggs are relatively inexpensive and have excellent nutritional quality (Ronsivalli and Vieira, 1992). However they can cause human health concerns if their shell surface contains bacteria and improper handling and unsanitary conditions lead to contamination of liquid or raw eggs (Vanderzant and Splittstoesser, 1992). De Reu et al. (2006) and Messens et al. (2007) also reported that bacteria on the eggshell increase the risk of their penetration and egg content contamination. In this study, eggs from cages were more hygienic because they had lower bacterial shell- contamination than floor eggs and those from nest boxes because these eggs were separated from excreta by the wire floor of the cages. Quarles et al. (1970) also found that eggs from hens kept on litter floors had greater bacterial contamination than those laid in rollaway nest boxes. Eggshell contamination increased with age, likely because litter quality deteriorated with time.

The well-being of laying hens plays an important role in egg production and stress can lead to lower egg production. No housing effect was found for total egg production, which could be because neither environment was a stressor in this study, but the interactions found between housing system and strain at different ages did not rule out the possibility of problems among birds in these housing systems. Significantly similar egg production for white-egg and brown-egg commercial layers was possibly a result in recent years of intensive selective breeding of commercial brown egg layers which has brought their production to levels similar to those of white egg strains (Scott and Silversides, 2000). Lower egg production by Cross hens could be due to the fact that although their parental lines have very good egg production, Cross strain has not been subjected to the intensive selective breeding used by industrial lines (Silversides et al., 2007).

Egg weight is genetically linked to the shell, albumen, and yolk weights although each has different heritabilities. In this study, the major contributing factor to egg weight was the yolk, although the heritability for yolk weight is lower (Washburn, 1979) than those for shell and albumen weights. Basmacioglu and Ergul (2005) also found higher yolk, shell, and albumen weights in eggs from floor pens than in eggs from cages, although Pištěková et al. (2006) found no influence of housing systems on yolk weight.

Albumen is the major determinant of internal egg quality and greater albumen height was found in eggs from cages. Lower albumen height in eggs from floor pens may be partly due to their exposure to ammonia (from litter), which affects albumen quality (Roberts, 2004). A similar housing effect was found by Süto et al. (1997). White eggs had greater albumen height than brown eggs and albumen height decreased with age for all strains in both environments. Silversides et al. (2006), who studied commercial strains housed in cages, show similar results. In contrast, Curtis et al. (1985) found better albumen quality in brown eggs than in white eggs, but it should be noted that they used different strains from the ones used for this study.

Yolk color was higher for eggs from floor pens than for eggs from cages. Nys (2000) reported that there is a common association between yolk color and acceptability of eggs as a food and some consumers may prefer eggs with higher yolk color. Brown eggs had darker yolk than white eggs in this study and might be preferred by consumers. Diet is the main contributing factor for yolk color (Leeson and Summers, 1991), and although all hens were fed the same diet, yolk color was different between commercial and non-commercial layers possibly due to the dilution effect of higher egg production by commercial layers. The difference between commercial lines could be attributed to genetic variation that is not related to productivity (Hocking et al., 2003). Age differences for the yolk color among strains could be caused by access to litter in the floor pens. Süto et al. (1997) and Pištěková et al. (2006) both found higher yolk color in eggs from floor pens than in eggs from cages, but provided no reason for the difference.

Another indicator of poor welfare is mortality (LayWel, 2006). Higher rearing period mortality in floor pens was because our LB hens had very high mortality but no major cause of this was determined. Significantly higher mortality in cages than in floor pens during the laying period was distributed evenly between the strains . Tauson et al. (1999) found overall higher mortality of LB hens in floor pens than in cages, which was largely related to feather pecking, with no difference between housing systems for Lohmann Selected Leghorn hens.

Caged hens spent more time drinking because they also tended to spend more time feeding (but non-significant in this study) and drinking and feeding are positively correlated (Carmichael et al., 1999). Alternately, drinking may be a stereotypic behaviour with hens playing with water out of boredom in the barren environment of cages. A similar finding of over drinking was found in pigs reared in pig-stalls (Terlouw et al., 1991; Terlouw et al., 1991a, b). Hester (2005) reported that hens in a barren environment become stressed, leading to overdrinking. Whichever is true, over drinking may be attributed to the barren environment in cages. Our results agree with the findings of Bessei (1986) who found that caged hens spent 14% of their time drinking and Gibson (1988) who found that hens on the floor spent only 6% of their time drinking. In this study, LW hens in cages spent more walking and drinking than did birds in floor pens and that may indicate that the strain is innately less able to adapt to cages.

Hens spent more time sitting in the morning and spent most time preening and Dustbathing in floor pen and they foraged more in the afternoon, indicating increased activity towards the end of the day. These results agree with those of Carmichael et al. (1999) who observed the behaviour of ISA Brown hens in a perchery system at different stocking densities. Generally, increased activity leads to lower performance due to higher feed consumption, but in this study, feed consumption, feed efficiency, and hen day egg production were influenced by the strain but not the housing system.

The hens in this study used perches mainly for roosting at night, and the nest boxes were used only for egg laying. Hens spent little time on the perches during the day, which is in contrast to the findings of Newberry et al. (2001) for younger pullets of a White Leghorn strain. Day time use of perches was low when these observations were made. During both day and night the White-egg layers, LW and HN, always used perches more than the Brown-egg layers, LB and Cross hens. In this study, the Brown-egg layers were also larger than the White-egg layers, which could suggest that perch use is linked to this trait.

Newberry (1995) reported that provision of environmental complexities in a barren environment not only stimulates the birds to perform natural behaviours, but also leads to improved production, livability, and feather condition, and reduced aggressive behaviours (Yasutomi and Adachi, 1987; Church, 1992; Gyaryahu et al., 1994). Gunnarsson et al. (1999) reported that if birds are exposed to perches early in life (by 4 week of age), cloacal cannibalism is reduced, as is the incidence of floor eggs. It has been observed that hens are highly motivated to use perches and nest boxes and that they suffer from reduced welfare when they are absent (studies on nest box usage: Smith et al., 1990; Ekstrand and Keeling, 1994; studies on perch usage: Olsson and Keeling, 2000). Design and location of these facilities impact their usage (Reed, 1994). Although our nest boxes were commercially produced and provided two levels congruent with the level of the perches, and birds were exposed to perches and nest boxes by 4 week of age, our results showed that not all strains were highly motivated to use them. White-egg layers used these facilities more than the Brown-egg layers and Brown-egg layers laid most of their eggs on floor. The findings of Olsson and Keeling (2000) are in agreement with our observations for the White Leghorn strains. Channing et al. (2001) observed that commercial brown egg layers used perches for resting during the day, and Duncan et al. (1992) reported that a strain of commercial brown egg layers used perches that were added to conventional cages more often than a White Leghorn strain, suggesting that use of perches depends on the specific strain being studied.

It is well documented that hens need more space to perform comfort behaviours such as body shaking and wing-flapping (Nicol, 1987). The absence of dust bathing in cages is obvious because there is no litter, but the absence of preening in cages could possibly be due to absence of this behaviour when these observations were made but not due to insufficient space (Nicol, 1987) or frustration among birds (Duncan, 1970). Preening helps to keep the plumage in good condition and an absence of preening facilitates observation of the incidence of gentle feather pecking by birds in cages. Without preening, a high incidence of feathers out of place may indicate that gentle pecking is frequent. A greater incidence of gentle feather pecking could be related to the absence of a litter substrate for foraging and dust bathing (Abrahamsson et al., 1996). This result in a redirection of the pecking that is part of foraging behaviour towards the feathers of other birds (Blokhuis and Arkes, 1984). Blokhuis (1986) believed that feather pecking depends on the motivation of hens to forage and severe feather pecking can be a welfare problem, although gentle but not the severe feather pecking was found in this study. The high frequency of gentle feather pecking by birds in cages during the afternoons may be related to the hens' higher motivation to forage at this time, which we found in floor pens. The hens may be highly motivated to forage whether they have the opportunity to do so or not. A higher frequency of pecking at the enclosure in cages could be as displaced foraging behaviour. Duncan (1970) and Duncan and Wood-Gush (1972) found increased cage pecking in experimentally frustrated hens, indicating hens in cages are frustrated.

Aggressiveness is primarily influenced by the number of birds in the immediate vicinity of a resource and by differential plumage markings (Estevez et al., 2002, 2003; Dennis et al., 2008). The absence of aggression during this study could be attributed to the fact that the study population was homogenous and stable.

Caged hens had full feather at the time of their housing but it deteriorated progressively with increasing age and birds had poor feather condition seen as large naked patches at the base of their necks and on their breasts. This was possibly due to the wear and tear by the cage wires during feeding. Floor hens had full feather cover throughout the trial. Caged hens had longer claws than floor hens because no abrasive claw-shortening devices were provided in the cages. These findings were supported by the findings of Vits et al. (2005) who also found longer claws in the birds kept in cages. No keel bone fractures were found in hens of either housing system, in contrast to the findings of Scholz et al. (2008) who reported that alternative housing systems produce more prone to keel bone deformities because of fractures caused by the inappropriate use or design of perches. However, keel bone deformities were quite prominent in caged hens in this study, most likely the result of pressure on this region by caged wires while the birds were feeding or due to osteoporosis in caged birds (Whitehead and Fleming, 2000). However, these twisted keel bones not appear to affect production (Singh et al., submitted). Elson and Croxall (2006) also considered that twisted keel bones were not harmful to the welfare of hens but in contrast Wilkins et al. (2004) considered twisted keel bones to be a serious welfare problem. All birds in cages had good foot condition whereas in floor pens, Cross hens had the worst foot condition and LW hens had the best foot condition, which support the findings of Wang et al. (1998), although they had severe foot problems in their study.

The housing system had an effect on different traits related to production and behaviour. Early egg production of HN hens was low in floor pens possibly because maturity was delayed for this strain in this environment, which could be a reflection of their lower body weight. Although lower body weight of HN hens in floor pens could be because this strain used the increased space more effectively for physical activity, but delayed sexual maturity only in floor pens can explain the effect of strain in that particular environment. No housing effect for feed consumption and feed efficiency was found in this study, but overall feed efficiency was best for HN hens possibly because of genetic differences in physical activity, physical condition, basal metabolic rate, body temperature, and body composition (Luiting, 1990).

Conclusions

It is clear that conventional cages, due to their barrenness, have inherent disadvantages for the welfare of hens because they restricted the hens' behavioural repertoire and resulted in higher mortality during the laying period and poorer feather condition of all strains. However, overall production did not differ between environments. A higher frequency of gentle feather pecking and pecking at the enclosure in cages suggests that hens were frustrated in that environment. The problem of longer claws in cages among all stains could be solved by providing claw-shortening devices (Glatz, 2002). On the other hand, it is also clear that there are disadvantages of floor pens due to the occurrence of floor eggs and the consequent requirement for more labour. Floor eggs for Brown-egg layers in floor pens might be reduced by putting the nest boxes at a lower level than that used in this study and bacterial shell contamination might be reduced by using roll-away nest boxes. In floor pens, mortality was higher for LB hens than for other strains during rearing period and foot condition score was increased. On balance, the birds' body weight, feather condition and egg shell quality deteriorated with age in cages but evidence from this study suggests that floor pens, while apparently providing an environment that permit laying hens to express a more diverse behavioural repertoire, are neither better nor worse than cages with respect to production and bird health. Because genotype is a deciding factor in the use of environmental complexities, their absence in conventional cages cannot be considered to be incontrovertibly detrimental to the welfare of laying hens. Each system offers its own advantages in regard to bird welfare.

It can be concluded that HN hens had the best feed efficiency, Cross hens had the best egg quality, and LB hens had best physical health in both housing systems. This study found interactions between environments, strains, and ages on production traits and behavioural responses suggesting that the strain should be considered when using alternative housing systems. These conclusions can only be applied to the four strains and two housing systems studied, but suggest the need for further studies on strain and environment interactions. It is therefore concluded, as Beilharz (1982) did, that selecting animals to suit their intended environment is as viable a solution to welfare problems as changing the environment to suit the animal.

Table 4.1 Summary of the most important welfare indicators of four strains of laying hens in conventional cages and floor pens (+++ best; ++ moderate; + worst; - not observed)

	Conventional cages				Floor pens			
Attribute	LW	HN	LB	Cross	LW	HN	LB	Cross
Hen day egg production	++	++	++	+	+++	+	++	+
Body weight	+	+	++	+++	++	+	+++	+++
Feed efficiency	++	++	+++	+	+++	++	++	+
Laying mortality	+	+	+	+	++	++	++	++
Standing	++	+++	+++	++	+	+	+	+
Foraging	-	-	-	-	++	+	+++	+++
Dust bathing	-	-	-	-	+	+	++	+
Wing flapping	-	-	-	-	+	+	+	+/-
Gentle feather pecking	++	++	+	+	+++	+++	+	+
Pecking at Enclosure	+	+	+	+	++	++	++	++
Feather condition	+	+	+++	++	++	++	+++	++
Keel bone deformity	+	+	++	++	++	++	++	+

LW: Lohmann White
HN: H&N White
LB: Lohmann Brown
Cross: A cross between Rhode Island Reds (♂) and Barred Plymouth Rock (♀)

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