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ASSESSING THE WELFARE OF LAYING HENS HOUSED IN CONVENTIONAL, MODIFIED AND COMMERCIALLY-AVAILABLE FURNISHED COLONY CAGES

by

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Abstract

The welfare of White Leghorn hens housed in conventional battery cages (CONV; 3 hens/cage), modified cages containing a nest box and perch (MOD; 3 hens/cage), and furnished colony cages containing a loose-litter lined dustbath (CWDB; 26 hens/cage) or closed dustbath (CWODB; 26 hens/cage) was assessed. In the first study, behaviour of CONV and MOD hens was observed during the prelaying period. CONV hens exhibited increased frustrated behaviours and fewer comfort behaviours, providing evidence of reduced welfare resulting from an inability to express normal nesting patterns.

Study 2 compared dustbathing behaviour in CWDB and CWODB. Increased bathing frequency, shorter duration to bathe, and longer bouts provided evidence of improved behavioural expression in CWDB. Sham bathing did not satisfy hen behavioural need as apparent from high bout frequencies, short durations, and interruptions to bathing activity. Social competition for the dustbath was problematic.

Bone health of all hens was examined in Study 3. Increased structural bone preservation and improved leg bone strength was afforded by movement and load-bearing activity in MOD, CWDB and CWODB. Improved humeral cortical bone density and breaking strength were only observed for hens with access to raised cage amenities that promoted wing loading. Improvements in bone condition were not the result of reduced egg production or quality.

Study 4 examined hen condition and productivity. Reduced feather condition, increased wound scores, and cannibalism in colony cages indicated reduced welfare due to large group size, however access to the dustbath contributed to improved feather cover. Egg quality was also improved in colony cages. Reduced nesting frustration and

opportunity to perch in MOD improved hen feather and foot condition. Maintaining small group size was critical to hen welfare.

Study 5 examined alternative layer housing environments in Europe. Achieving a balance between hen welfare and productivity is possible in aviaries, free run, range and organic production systems, and requires key management strategies.

Collectively, these studies indicate that alternative cage and non-cage housing systems provide welfare benefits to hens that cannot be realized in conventional battery cages. Layer housing environments must continue to evolve with our increased understanding of hen behavioural and physiological needs.

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the welfare of generations of laying hens to come, and their contribution is not without recognition or appreciation.

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Dedication

I dedicate this work to my beloved Ted and my beloved Bob.
You inspired me, guided me, nurtured me, waited for me, believed in me, shared with me and loved me without fail. I am eternally and gratefully yours.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AI – Avian Influenza
Aggr Peck – aggressive peck
APA – Swiss Federal Act on Animal Protection
AWA – Swedish Animal Welfare Act
AWO – Animal Welfare Ordinance
BMD – bone mineral density
BWDiff – average bodyweight difference
CAP – Common Agricultural Policy
CH – country code - Switzerland
CONV – conventional battery cage
CWDB – commercial colony cage with dust bath
CWODB – commercial colony cage without dust bath
DB – dustbath
doorfr. – doorframe
EFTA –European Free Trade Association
EMC – Edinburgh Modified Cage
EU – European Union
f – frequency
FAL – Federal Ministry of Consumer Protection, Food and Agriculture - Germany
FAWC – Farm Animal Welfare Council – Switzerland
FVO – Federal Veterinary Office – Switzerland
kgf – kilogram force
h – hour
h : l – heterophil : lymphocyte
HACCP – Hazard Analysis Critical Control Point
HD – hen day
HH – hen housed
md - mean duration

mg – milligrams
mgQCT – mass (mg) of bone as determined by QCT
min - minutes
MOD – modified cage
NB – nest box
NRC – National Research Council
pd – percent duration per hen
QCT – Quantitative Computed Tomography
r – correlation coefficient
s – seconds
SCWL – Single Combed White Leghorns
SEM – Standard Error of Mean
SG – Specific Gravity
SAWA – Swedish Animal Welfare Agency
SJV – Swedish Board of Agriculture (Svenska Jordbruksverket)
SVA – Swedish Veterinary Association
SVC – EU Scientific Veterinary Committee
UN – United Nations
wk - week
WTO – World Trade Organization

Chapter 1

Assessing the Welfare of Laying Hens Housed in Conventional, Modified and Commercially-Available Furnished Colony Cages

The following chapter provides a general introduction to and the rationale for the studies that follow. Introductions to the individual chapters provide a more comprehensive overview for each specific study.

1.1 Introduction

Battery cages for layer hens were developed in the 1940's to accommodate production expansion and to reduce disease transmission by improving hygiene (Duncan, 2001). The advantages afforded by this husbandry system have secured its application and it is estimated that 70 to 80% of layer flocks in the world are housed in cages (Tauson, 1998). Wire flooring promotes improved hygiene over floor litter systems since birds are separated from fecal matter, and small group size reduces the frequency of aggressive and cannibalistic behaviour (Duncan, 2001). Battery cages facilitate litter management and improve environmental conditions by reducing dust and ammonia levels (Tauson, 1998). In addition, production costs are lowered since morbidity and mortality are reduced with improved hygiene and reduced aggression, the number of cracked or soiled eggs is reduced since eggs are collected, stocking densities are higher, and labour intensity and costs are reduced through automation of feeding and cleaning systems and egg collection (Appleby, 1998; Duncan, 2001).

The use of battery cages has, however, stimulated considerable controversy since conventional cages compromise animal welfare. High stocking densities reduce physical and psychological space, and birds are unable to escape from aggressive cage mates (Duncan, 2001). Wing flapping is prevented and exercise is limited, which contributes to metabolic disorders (Tauson, 1998). The absence of nesting facilities causes frustration, and birds are prevented from exhibiting natural perching and dustbathing behaviours

(Duncan, 2001). In addition, housing birds in battery cages results in an increase in the incidence of foot lesions such as toepad hyperkeratosis (Duncan, 2001).

Public awareness and concern over the use of cages for layer hens is increasing and in the European Union, a directive has been approved that prohibits new investment in conventional cages beyond 2003 and bans their use after 2012. In the United States, corporations such as McDonald's and Burger King have responded to public pressure by decreasing layer cage stocking density, and setting measurable welfare guidelines and auditing systems that verify supplier compliance (Mayer, 2002). Canadian retailers have implemented similar stocking density standards.

To resolve the welfare concerns surrounding conventional cages, systems such as free run and free range production or furnished cages, environments that endeavour to satisfy the hens' behavioural needs, have been developed. However, none of these systems has proven to be economically desirable since consumers are required to incur the increased costs of implementation and maintenance. A recently emerging trend to improve the welfare of caged hens while maintaining the benefits of cage systems seeks to modify the environment of existing conventional cages. Modified cages aim to provide hens with the opportunity to perform behaviours that are otherwise absent or incompletely performed when birds are housed in conventional battery cages (Lindberg and Nicol, 1997). The Get-away cage, first developed by Bareham (1976) and Elson (1976), included nesting sites, perches and dustbathing facilities, design features that allowed groups of 15 to 25 hens to express many natural behaviours (Abrahamsson et al., 1996). The Edinburgh Modified cage, designed to house four to six hens, also featured a perch, nest and sand bath, but facilitated inspection due to its smaller size (Abrahamsson et al., 1996). Studies involving modified cages have revealed that many of the behavioural problems that occur in cages can be reduced or prevented by increasing cage area and height and by providing a nest box, perch and dustbath (Appleby, 1998). Adaptations to housing systems intended to improve hen welfare can be assessed by evaluating hen behavioural, physiological, condition and production measures.

1.2 Nesting Sites

Provision of a suitable nesting site is widely considered to be an essential welfare requirement for the laying hen (Reed and Nicole, 1992). Prelay behaviour, which includes nest site selection and nesting behaviour, has been observed whether hens are housed in feral conditions, pens or semi-extensive systems (Duncan et al., 1978). Furthermore, hens housed in cage systems have shown a willingness to work to gain access to a suitable nest site (Smith et al., 1990) and some hens will perform vacuum nest building on wire mesh (Wood-Gush, 1972) suggesting that nesting is essential for the laying hen (Wall et al., 2002). When nest sites are absent, oviposition may be delayed, and increased pecking, pacing, displacement preening and nest calling may occur during the prelay period (Duncan and Wood-gush, 1972; Reed and Nicole, 1992), behaviours which are thought to indicate frustration (Wood-Gush, 1972). Providing caged layer hens with a nest may also improve egg quality. Smith et al. (1993) observed a lower incidence of cracked and dirty eggs when nests were present in conventional cages.

1.3 Nest Location

Considerable effort has been dedicated to designing a nesting site that is both attractive to the laying hen and functional for the producer, and can be included in or attached to the cage. Since most non-nesting behaviour is performed outside the nest site, allocating a portion of the minimum required floor space to a nest site would reduce available space for other behaviours such as preening and resting (Appleby, 1990; Reed and Nichol, 1992). Furthermore, decreasing available floor space might force hens to perform non-nesting activities in the nest box, possibly resulting in damage to the eggs, disturbance to nesting behaviour, and an increase in nest soiling (Appleby and Hughes, 1990; Reed and Nichol, 1992). Therefore, it is generally agreed that sufficient nesting space should be provided, in addition to the minimum recommended floor space requirements (Appleby, 1990; Appleby and Hughes, 1990; Reed and Nichol, 1992).

1.4 Nest boxes

Experiments designed to determine the preferred features of a nest site have revealed that the degree of enclosure (Appleby and MacRae, 1986; Appleby, 1990) and the type of nest substrate (Appleby, 1990) are two key aspects that affect hen use. Bareham (1976) observed that when metal nest boxes with an opening at the front were installed in conventional battery cages, the majority of eggs were laid in the nest boxes. In addition, hens in cages containing the nest enclosures reached 50% hen housed production level before hens in cages without nests. The author suggested that enclosed nest boxes might have provided isolation from cage mates, satisfying the compulsion to seek an isolated nest site, a behaviour commonly practiced by red jungle fowl (Bareham, 1976). A study conducted by Appleby (1990) compared battery cages containing traditional wooden nest boxes, to control cages, cages containing a wooden surround, cages containing a fibreglass rollaway nest hollow, and cages containing a fibreglass hollow enclosed by a wooden surround. Only a small proportion of hens were found to use nest hollows for laying and hollows were often soiled (Appleby, 1990). In addition, hens that nested in sites enclosed by surrounds appeared more settled (Appleby, 1990). Similarly, Reed and Nichol (1992) found that the amount of time spent in plastic hollow rollaway nests and the number of visits to the nests, increased when solid partitions were present between multiple nest sites. The authors concluded that enclosure enhanced the attractiveness of the nesting environment. Enclosure may also contribute to reduced stress levels and thereby improve hen welfare. Barnett et al. (1997) compared corticosterone concentrations and h:l ratios of birds housed in control cage and floor pens to those of birds housed in cages containing solid sides. Hens housed in modified cages showed significantly lower corticosterone and h:l ratio values, indicating that stress levels were reduced by enclosure. In this study, feather condition and cover were also significantly improved, probably due to a reduction in pecking behaviour within and between cages, which may have further contributed to reduced stress levels.

1.5 Nest Lining

Studies involving nest substrates indicate that hens prefer nests that are lined, to those on wire floor (Hughes, 1993; Abrahamsson et al., 1996). Litter and artificial turf are two suitable substrates (Appleby, 1998). Wood-gush (1972) observed that when litter was absent from the nest site, some hen strains performed excessive prelay pacing, indicating frustration, and that a considerable amount of energy was expended by performing this stereotyped behaviour. Bareham (1976) found that in cages containing litter-filled nest boxes, the majority of eggs were laid in the nest box, suggesting that the presence of litter provided adequate stimulation for complete nesting behaviour. Bareham (1976) also observed a visible difference in feather condition between birds housed in control cages and those housed in cages containing litter-filled nest boxes. The author attributed this finding to reduced pecking, as compared to control cages, since it has been previously shown that the absence of litter in battery cages contributes to the high incidence of feather pecking (Hughes and Duncan, 1972). However, addition of loose material to the nest may stimulate other behaviours. Appleby (1990) found that when wood shavings were provided as a nest lining, dust bathing was also stimulated, resulting in broken eggs. Bareham (1976) also found that in addition to nesting activity, the litter-filled nest boxes were used for scratching litter, dust bathing and roosting at night. Appleby (1990) recommended that if litter nests were provided, dust baths would likely be needed as well, to prevent dust bathing in the nest box.

To determine the importance of loose material in attracting hens to nest sites, Duncan and Kite (1989) compared nest sites containing a mouldable beanbag to those containing feathers and litter. The authors found that although hens were initially attracted to the loose litter, by the time of first nest site selection, hens were equally attracted to nests containing a beanbag and by the time the sixteenth egg was laid, hens showed less interest in the loose litter nests. This suggests that the presence of loose nesting material is not essential for the hen, and that a substrate that allows expression of moulding behaviour with foot and body movements is more rewarding (Duncan and Kite, 1989). In a study comparing unlined nest hollows to those lined with neoprene rubber, Reed and

Nichol (1992) found that hens were most attracted to neoprene-lined hollows when a strip of artificial grass was mounted to the cage, at the back of the nest. The authors concluded that a small amount of substrate such as artificial turf, present in only a part of the nest, might sufficiently satisfy nesting behaviour requirements in laying hens. Less lining would also improve nest hygiene (Reed and Nichol, 1992). To further investigate this finding, Wall et al. (2002) compared Astroturf-lined nests covering 30, 50 or 100% of the nest bottom wire area. For nests containing 30 or 50% Astroturf, the lining was placed at the back of the nest, such that the wire flooring at the front of the nest was left uncovered. Since a lower proportion of eggs were laid in nests provided with less turf, the authors concluded that less lining did not provide an acceptable nesting environment, but might have been more attractive to the hens if the turf could have been viewed from outside the nest (Wall et al. 2002).

1.6 Nest Dimensions

Nest dimensions and the number of available nest sites also require consideration when designing modified cages. Although provision of more than one nest box may reduce competition between hens in multi-bird cages (Appleby, 1998), disturbed nesting behaviour may result if birds experience difficulty choosing a site. Appleby and Hughes (1990) and Appleby and Smith (1991) observed greatest use of nest boxes when a single nest box, large enough for two birds to nest simultaneously, was provided in cages housing 4 to 5 birds. When two nest boxes were provided, birds moved between the nest boxes and prelay behaviour was disturbed (Appleby and Smith, 1991). Since hens are unable to turn around in smaller boxes, the minimum recommended size for a nest box constructed for medium weight hybrid layers is 25cm wide X 25cm deep (Appleby, 1990). For cages containing large groups of hens, nest box width is of special consideration when constructing rollaway-type nests where eggs roll onto an egg cradle, since eggs may accumulate in the cradle, increasing the risk of collisions and cracking (Wall et al., 2002). However, for cages housing 4 or 5 hens, a nest width of 24 to 25 cm is common. The Edinburgh Modified cage, a modified traditional battery cage designed to improve the welfare of laying hens, contains a rollaway nest box of dimensions 24cm wide X 50cm deep, intended for use by 4 hens (Appleby and Hughes, 1995). Similarly, the Gleadthorpe cage, a modified cage constructed from two conventional cages, houses a nest box of 24 X 50 cm designed for 5 to 7 hens (Lindberg and Nicol, 1997). Abrahamsson et al. (1996) constructed a modified cage for 5 hens containing a nest box of dimensions 23 cm X 50 cm, and Wall et al. (2002) constructed a nest of the same dimensions in a cage housing 6 hens. In all of the above studies, nest dimensions proved sufficiently adequate to attract hens to the nest sites.

1.7 Nest Box Doors

Previous studies have shown that even when perches are provided, hens have a tendency to sit or stand on the rims of nests and nest boxes, especially at night (Bareham, 1976; Appleby, 1990; Reed and Nicol, 1992). This can lead to soiling of nests and eggs. Smith et al. (1993) designed nest box doors that could be closed such that entry to the nest box was limited to nesting periods, and successfully reduced defecation in the nest box. Abrahamsson et al. (1996) adopted and modified this design for their enriched cages, so that nest box doors were time controlled, opening 30 minutes before lights came on and closing 30 minutes before lights went out. As an additional modification, Lindberg and Nicol (1997) designed the nest box door so that birds were able to leave the nest box without difficulty once the door was closed in the afternoon. More recently, Wall et al. (2002) designed wooden nest boxes that provided two openings, one near the feed trough and another at the back of the cage. The door closest to the feed trough enabled passage into the nest box, whereas the door at the back of the cage enabled passage out of the nest box. Although the doors were not difficult to push open, the design may have hindered nest box inspection, reducing motivation to enter, and in some cases, hens were unable to understand how to enter the nest box (Wall et al., 2002).

1.8 Perches

Another simple modification to conventional battery cages that improves bird welfare is the addition of perch. Perches encourage roosting behaviour and provide hens with a place to stand other than a sloping wire floor (Tauson, 1984; Appleby et al., 1998). Perches may also reduce foot problems such as toe pad hyperkeratosis, which is believed to be caused by pressure on the claw fold as a result of standing on a sloping floor (Appleby and Hughes, 1990; Duncan et al., 1992; Abrahamsson et al., 1996). Improvements in bone strength have also been observed for birds housed in cages with perches (Hughes and Appleby, 1989; Duncan et al., 1992), although these findings have not been consistent (Appleby et al., 1993; Abrahamsson et al., 1996). In the layer hen industry however, perches are rarely provided in cages since some hen strains prefer to lay their eggs while standing on a level perch than on a sloping floor. This results in an increase in the number of cracked and soiled eggs (Tauson, 1984, Duncan et al., 1992). Studies have also indicated that perches may cause deformations or lesions of the keel bone (Appleby et al., 1993; Abrahamsson et al., 1996). Appleby et al. (1993) observed that keel bone depressions were present in 43% of hen cages containing perches, but in only 4% of conventional cages. Such deformations are thought to occur as a result of the combined effects of osteoporosis and pressure on the sternum during roosting (Appleby et al. 1993).

The length, position, shape and material used to construct the perch, are all important considerations for design. In general, it is recommended that sufficient space be provided for all birds in the cage to roost simultaneously (Appleby and Hughes, 1990; Appleby et al., 1993 Appleby, 1998). This is especially important at night, when perch use is significantly higher. Abrahamsson et al. (1996) observed that while only 30% of hens roosted during the day, perch use increased up to 96% at night, and Appleby and Hughes (1990) found that although perch use was significantly higher at night, 100% use was only achieved when excess space was provided. While several studies have shown that 14cm of perch space per bird, for hens of a medium hybrid strain, is necessary to increase roosting activity (Appleby et al., 1993; Abrahamsson et al. 1996), other studies have found that 12 cm perch length per bird is sufficient (Wall et al. 2002).

Perches should be positioned in the cage such that birds have both enough space to stand behind the perch and enough space in front, thereby preventing hens from having to stand on the perch to feed (Abrahamsson et al., 1996, Appleby et al., 1998). Depending on cage depth, perch position has ranged from 9cm from the back of the cage and 16cm from the cage front (Reed and Nicole, 1992) to 24cm from the back of a cage that was 45 cm deep (Abrahamsson et al., 1996). Appleby (1998) recommends placing the perch in the middle of the cage. Perches are typically positioned high enough off the cage floor for eggs to roll underneath, should hens choose to lay their eggs at the perch, and to prevent accumulation of fecal matter under the perch (Appleby, 1998). The majority of perches are raised 7 to 9 cm off the floor, as measured from the center of the perch (Appleby et al., 1993; Abrahamsson et al., 1996; Wall et al., 2002).

Wooden perches of rectangular cross section are preferred over other designs, however plastic or metal perches are also used. The design of the perch should ensure that keel bone deformation and the onset of bumblefoot are minimized (Tauson and Abrahmsson, 1996). Perches constructed from artificial materials such as plastic, for example, have been shown to impair foot condition (Abrahamsson et al., 1996; Tauson and Abrahmsson, 1996), and rounded perches are more difficult to grip (Appleby and Hughes, 1990). Rounded perches may also cause foot abrasions and discourage roosting (Duncan et al., 1992). The most common perch dimensions are 5 cm deep and 2.5 cm high (Appleby et al. 1993).

1.9 Dustbaths

Of the cage modifications necessary to improve hen welfare, addition of a dustbath remains most disputed. Dustbathing in poultry appears to be a highly motivated behaviour, since it occurs even in the absence of substrate, in the form of sham dustbathing (Lindberg and Nichol, 1997), and evidence exists to indicate that hens experience frustration when prevented from dustbathing (Vestergaard et al., 1990). Most incidences of dustbathing on a wire floor occur close to the feed trough, perhaps because food provides an attractive alternative for pecking and foraging in the absence of other loose material (Lindberg and Nichol, 1997). Appleby et al. (1993) and Lindberg and

Nichol (1997) observed that the duration of dustbathing bouts occurring on wire flooring were significantly shorter than in dustbaths, and were fragmented. The authors suggested that unsuitable substrate and frequent disturbance of dustbathing activity in the battery cage might lead to such abnormal behaviour. Improvements in foot and claw condition have also been found when dustbaths are available (Appleby et al., 1993; Smith et al., 1993). However, observed reductions in the incidence of feather pecking in the presence of loose material may provide the most compelling argument for provision of a dustbath (Appleby et al., 1993). Lindberg and Nichol found that hens housed in conventional cages experienced greater feather loss than hens housed in modified cages containing dustbaths, possibly resulting from a combination of increased feather pecking activity and abrasion from the wire floor during bouts of vacuum dustbathing. Dustbathing is thought to be stimulated by the presence of ectoparasites and by high lipid levels in the feathers, thereby functioning to maintain plumage condition (van Liere et al., 1990).

The arguments in favour of providing a dustbath, however, are diminished by practical problems associated with this facility. Inclusion of a dustbath requires regular replenishing of substrate, and hens may choose to nest in the dustbath (Lindberg and Nichol, 1997). In addition, provision of a dustbath does not ensure complete absence of sham behaviour (Lindberg and Nichol, 1997), suggesting that while sham dustbathing on the battery floor may appear to be sub-optimal to humans, it is sufficiently adequate for layer hens. To examine the motivation for dustbathing, Widowski and Duncan (2000) compared the willingness of hens to work to acquire access to a dust bath when hens had been deprived of the opportunity, with their willingness to work when they had recently dustbathed. The authors found that deprived hens were not significantly more willing to work than hens who had recently dustbathed. As well, when non-deprived hens worked to gain access to the dustbath, they did not always perform the behaviour. These findings suggest that while dustbathing may prove pleasurable for the hen, the behaviour may be more motivated by opportunity than need (Widowski and Duncan, 2000).

When a dustbath is provided in a modified or enriched environment, it is generally accepted that access is restricted, to reduce the incidence of nesting therein. Dustbathing has a strong diurnal rhythm and primarily occurs in the afternoon (Appleby et al., 1992; Appleby et al., 1993). Consequently, dustbathing facilities are typically opened between 5 to 9 hours after lights have been turned on, and are closed again 30 or 45 minutes before lights are turned off (Abrahamsson et al., 1996; Lindberg and Nichol, 1997; Wall et al., 2002). Hens appear to prefer a fine, dry material such as sand (van Liere et al., 1990; Appleby et al., 1992; Appleby et al. 1993) or peat moss (Widowski and Duncan, 2000) for dustbathing.

1.10 Evaluating Hen Welfare

Mench and Mason (1997) describe behaviour as one of the most easily observed indicator of animal welfare. Since behaviour reflects the actions of an animal to change and control its environment, observing behaviour can provide information concerning needs, preferences and internal states (Mench and Mason, 1997). In addition, understanding the development and function of behaviours, and hence the importance for their expression, is possible by relating behaviour to the social and ecological environment in which an animal lives (Martin and Bateson, 1993). Appleby (1999) suggests that the majority of behavioural evidence reflects negative or reduced welfare states, such as pain and suffering. However, positive welfare states are also evident from the expression of behaviours that are pleasurable or typically occur in an animal's natural habitat (Widowski and Duncan, 2000). Welfare status is also evidenced by the occurrence of abnormal behaviours, such as stereotypes (Appleby, 1999).

Whereas classical methods of recording behaviour required researchers to record observations either on paper or audiotape, use of a professionally developed manual event recorder can facilitate the collection, management, analysis and presentation of behavioural data (Noldus, 2002). The Observer®[1], one such program, is especially intended for recording activities, postures, movements, positions and social interactions (Noldus, 2002). Although the program can be used during live observations, video recordings allow the observer to capture details that may not have been detected otherwise or that were partially missed yet could not be retrieved in a live scoring situation. Tapes and media files can be repeatedly observed to refine observations or to replicate observations. Video images are also especially useful when multiple subject actions are incorrectly translated into one or a few movements, because they occur so rapidly.

The impact of housing environment on laying hen welfare can be further assessed by examining indices of hen physical condition. Scoring of the plumage condition and wounds to the head and vent region, for example, are reliable measures of hen behavioural traits such as feather and aggressive pecking (Hughes and Duncan, 1972). Evaluation of foot and claw condition, and keel bone deformation may indicate advantages to or inadequacies with the housing environment (Tauson et al., 1984; Appleby and Hughes, 1991).

Bone strength and bone density are additional physiological measures of hen welfare. A high incidence of bone fragility has been observed in layer hens housed in cages and is attributed to the development of osteoporosis (Knowles and Wilkins, 1998: Cransberg et al., 2001). Osteoporosis is characterized by a deficiency in the quantity of fully mineralized structural bone throughout the skeleton, which may increase susceptibility to bone fractures (Whitehead and Fleming, 2000). Structural bone in the layer hen is formed during growth, provides structural integrity and consists of cortical and cancellous, or trabecular bone (Whitehead and Fleming, 2000; Cransberg et al., 2001). Non-structural, medullary bone formation begins when a hen reaches sexual maturity and continues throughout the laying cycle. Since osteoblast activity is regulated by estrogen, it is believed that increases in circulating estrogen levels stimulate medullary bone formation rather than promote structural bone development (Whitehead and Fleming, 2000). Hudson et al. (1993), who examined bone development in layer hens, were unable to detect fluorochrome label incorporation into the cortical bone of mature birds. Moreover, since medullary bone serves as a labile calcium source for eggshell formation, reconstruction of this non-structural bone may rely on mobilization of cancellous and cortical bone (Knowles and Wilkins, 1998). Cransberg et al. (2001) observed that a 50%

decrease in layer hen cancellous bone volume between 16 and 31 weeks of age, coincided with a two-fold increase in medullary bone.

Chronic reliance on cancellous and cortical bone due to high levels of egg production, and egg production by underweight pullets may ultimately result in the onset of osteoporosis (Cransberg et al., 2001). The development of osteoporosis is accelerated by inactivity (Whitehead and Fleming, 2000). Lanyon et al. (1986) observed that osteoporosis could be prevented in layer turkeys by subjecting wing bones to dynamic loading forces, thereby maintaining bone thickness and functional structure. Furthermore, these researchers determined that even under conditions of calcium deficiency, bone loading increased bone mass and breaking strength.

Providing perches in battery cages, where lack of activity otherwise contributes to bone loss, has been shown to have a direct effect on bone volume. Hughes and Appleby (1989) compared tibia strength of hens housed in conventional battery cages in the presence or absence of a perch, and found that breaking strengths were significantly higher for birds housed in cages with perches. The authors suggested that use of perches increases static and dynamic forces. Whereas dynamic forces are required to step onto or off the perch, sitting on and gripping the perch, as well as supporting the hen's weight requires continuous muscle contraction. Numerous studies have also determined that bone volume and breaking strength are increased by provision of perches in battery cages (Duncan et al., 1992; Hughes and Wilson, 1993) or by housing birds in environments that do not restrict movement and exercise (Knowles and Broom, 1990; Fleming et al., 1994).

Since egg production has neared the hen's biological limit of producing one egg per day, determining the quality of eggs produced has become a primary concern (de Ketelaere et al., 2002). Egg quality can be affected by environmental conditions such as temperature and humidity, or design of the housing and floor systems, but is also a reflection of hen nutrition, age, health (Hamilton, 1982) and overall welfare. Shell strength reflects the ability of the eggshell to resist breaking when external forces are applied, and is an important measure of overall egg quality (Hamilton, 1982; de Ketelaere et al., 2002). Whereas the material strength of the shell is determined by the type of minerals and organic compounds that form the shell and their specific interactions, the structural strength of the shell is derived from the shape, size, and thickness of the shell, and the shell distribution over the egg (Hamilton, 1982). Egg size and thickness not only vary from day to day, but also as the hen matures. The thickness of the shell varies throughout the egg and is thicker at the pointed end than at the blunt end (Hamilton, 1982). The shell is thinnest, but most uniform at the equator (Tyler, 1961).

Techniques used to measure shell strength include indirect measures such as specific gravity or non-destructive deformation, and direct measures including resistance to impact, and depression fracture force, or breaking strength (Hamilton, 1982). Whereas indirect measurements are simple techniques that can be performed quickly, can be repeated and permit hatching of the egg, direct measures are destructive in nature, and rely on highly accurate compression speeds and consistency of egg placement (de Ketelaere et al., 2002). Indirect measures of shell strength are typically correlated with other, directly measured values such as egg weight, length, diameter, and shell weight and thickness (Hamilton, 1982).

Specific Gravity (SG) is one of the most widely used techniques for determining shell quality since the method is inexpensive, simple and practical to perform and is completed quickly (Hamilton, 1982). The floatation method involves the sequential immersion of eggs, contained in a wire basket, in a series of saline solutions that increase in SG, ranging from 1.060 to 1.104. Typical increments chosen are 0.002 to 0.005. The SG of the saline solution where the egg is first seen to float is the approximate SG value for that egg (Hamilton, 1982). Since an egg will float when its density is lower than that of the salt solution, a higher SG reflects a more dense egg and hence a higher quality shell. The SG of the saline solution is measured using a hydrometer and should be monitored repeatedly. Saline solutions should also be maintained at a constant temperature since SG is temperature dependent. Furthermore, egg temperature should be equilibrated with the temperature of the environment prior to testing, to prevent cooling of the saline solution when eggs are immersed (Hamilton, 1982). Egg storage times should also be standardized since SG decreases with storage (Silversides and Scott, 2001).

1.11 Objectives

To provide North American producers with viable housing options for promoting laying hen welfare, the purpose of this research was to assess the welfare of laying hens housed in cage and non-cage environments. Specifically, the objectives were to modify conventional battery cages and to evaluate the welfare of Shaver White Leghorn hens housed in conventional cages, the modified cage environments and commercially-available, furnished colony cages by examining behavioural, physiological, condition and production differences between the housing environments. It was hypothesized that modifications to conventional battery cages would enhance bird welfare in a comparable manner to furnished colony cages, while allowing producers to make use of existing cage capital. For producers interested in transitioning to non-cage housing environments, an additional objective was to evaluate cage-free production systems that have successfully been implemented in Europe.

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Chapter 2

Behaviour of White Leghorn Hens Housed in Conventional and Modified Battery Cages During the Prelaying and Laying Period

This chapter has been prepared in the format of the scientific journal Applied Animal Behavioural Science and a manuscript version has been submitted to the Journal for review.

2.1 Abstract

A study was conducted to assess the welfare of White Leghorn hens housed in conventional (CONV) and modified (MOD) battery cages by evaluating behaviour during the prelaying and laying period. Hens raised on floor litter were housed in either CONV cages, or in MOD units containing a nest box and perch, from 19 to 65 weeks. Location of egg laying was assessed on 2 consecutive days, every 4 weeks, between 20 and 64 weeks. Locomotive, agonistic, stereotyped, comfort, resting and ingestive behaviours, as well as the location of these activities during the prelaying and laying periods were recorded by continuous focal animal sampling at 35 weeks. Consistently high use of the nest by MOD hens throughout the study indicates that a suitable and preferred nesting environment was created in MOD. Birds in CONV cages exhibited increased incidence of, and time spent performing stereotyped pacing, escape and bobbing activity, performed more restless and fewer restful behaviours, and demonstrated increased aggression over MOD hens, both prior to and post oviposition. In contrast, hens in MOD cages engaged in nest inspection and building activities, maintained elevated levels of rest and comfort behaviours throughout the prelaying and laying period, and quickly resumed feeding and grooming activity post oviposition. These findings suggest that in the absence of a nest site, hens in CONV cages experienced daily frustration and discomfort prior to oviposition, and recovered less quickly from this stressful event. This study emphasizes the importance of providing nesting facilities in cage systems to improve the welfare of caged hens, and demonstrates a viable solution for incorporating nests in conventional cages.

2.2 Introduction

In the laying hen (*Gallus gallus domesticus*), the onset of prelaying behaviour is intrinsically regulated by ovulatory hormones (Wood-Gush and Gilbert, 1973). Approximately 24 hours after ovulation, estrogen and progesterone production by the post-ovulatory follicle (Dick et al., 1978) stimulate hens to begin nest site selection and nest building behaviours (Gilbert and Wood-Gush, 1968; Wood-Gush and Gilbert, 1973, Appleby, 1986). Hens are therefore motivated to express prelaying behaviour with each ovulation, even when the ovum fails to reach the oviduct, or to develop into a hard-shelled egg (Wood-Gush, 1963).

Prelay onset is characterized by an increase in locomotor and investigatory behaviours (Wood-Gush, 1975; Duncan et al., 1978), however, the behavioural elements expressed are highly dependent upon the environment in which hens are housed (Duncan et al., 1978; Wood-Gush, 1971). Whereas, for example, the increased locomotion of free-living hens appears purposeful, with hens gradually moving towards a secluded nest site (McBride et al., 1969; Duncan et al., 1978), pen-housed birds appear more restless (Wood-Gush, 1963; Wood-Gush and Gilbert, 1969a) and walk about an enclosure examining multiple nest areas (Wood-Gush, 1963). In environments devoid of nest sites, such as conventional battery cages, birds exhibit prolonged locomotor behaviours, shorter sitting bouts, and fewer nest-building activities (Wood-Gush and Gilbert, 1969b; Meijsser and Hughes, 1989), or may redirect nest-building at seemingly unsuitable substrates such as the cage wire floor (Sherwin and Nicol, 1993).

Since prelaying behaviour is programmed to occur in mature laying hens, and variation in behavioural elements is apparent as nesting opportunities become limited, it has been questioned whether hens without access to a nest site are behaviourally deprived. Indeed, studies examining behavioural priorities indicate that hens are not only highly motivated to access nest sites prior to oviposition, but that their demand for this resource is inelastic. Hens, for example, will squeeze through increasingly narrow passages to gain entry to a nest box (Cooper and Appleby, 1995;1996a) or will repeatedly enter trapnests, even if a consequence is prolonged food and water deprivation (Duncan, 1978). Smith et al. (1990) unexpectedly observed that hens without access to a nest site invested considerable time and effort learning to manipulate sliding doors that enabled them to access a closed dust bath. Hens who were successful in their efforts, repeatedly chose to oviposit in the dust bath, even though their speed and efficiency of door opening did not improve with experience. Cooper and Appleby (1995) demonstrated that hens who had no previous experience performing nesting behaviour in a littered nest box were equally resolute to locate a suitable nesting site as were experienced hens, suggesting that the high value placed on an appropriate nest site is unrelated to prior experience. Additional behavioural studies provide evidence that laying hens suffer when deprived of a suitable nest site. Birds may delay oviposition as a consequence of stress (Hughes et al., 1986), and characteristically exhibit symptoms of severe frustration. In conventional battery cages for example, hens will perform exaggerated or stereotyped pecking, pacing and escape movements (Wood-Gush, 1971, Mills and Wood-Gush, 1985, Brantas, 1980), but display fewer comfort (Tanaka and Hurnik, 1991; 1992) and resting behaviours (Meijsser and Hughes, 1989; Webster and Hurnik, 1990a).

The above physiological and ethological findings have contributed to the widespread acceptance that preventing hens from performing prelaying behaviour is a severe welfare concern (FAWC, 1986), and that providing laying hens with a suitable nest site is an essential welfare requirement. As a consequence, legislative policies in the European Union have addressed these concerns by requiring the provision of a nest box in all cage systems as of 2012 (CEC, 1999). In North America however, little consideration has been dedicated to adopting similar changes (Duncan, 2001), and laying hens continue to be predominantly housed in cages devoid of a nest site.

It has been suggested that modifying conventional battery cages by incorporating nest boxes could encourage acceptance of housing systems that better meet the welfare needs of laying hens, while accommodating the goals of intensive production (Bareham, 1976; Sherwin and Nicol, 1992; 1993; Hughes 1993). To provide North American producers with a viable option for promoting hen welfare using existing cage capital, and thereby encourage the adoption of welfare-conducive changes to cage systems, we designed an experimental cage based upon the findings of previous modified cage research. The objective of the present study was to assess the welfare of White Leghorns hens housed in the modified battery systems and in conventional cages by evaluating hen behaviour during the prelaying and laying period. We hypothesized that hens in cages without nest sites would exhibit increased frequency and duration of stereotyped, locomotive and agonistic behaviour, and displaced ingestive activity, and reduced frequency and duration of comfort and rest behaviours, than hens in modified cages.

2.3 Materials and Methods

This research was conducted in accordance with the Canadian Guide to the Care and Use of Experimental Animals (CCAC, 1993), and was authorized by the Faculty Animal Policy and Welfare Committee at the University of Alberta.

2.3.1 Animals and Management

One-day old White Leghorn layer chicks originating from Shaver parent breeder stock were obtained from a commercial supplier and were housed at the University of Alberta Poultry Research Centre, Edmonton, Alberta, Canada. Chicks were raised on floor litter in pens of 50 birds, and were beak trimmed with a heated blade trimmer at 1 week of age. At 19 weeks, birds were randomly allocated to one of two cage treatments housed within the same room. Day length was gradually increased from 10 hrs (0700 to 1700) at 20 weeks to 14 hrs (0500 to 1900) at 24 weeks. From 30 weeks until the end of the trial, one additional hour of light was introduced between midnight and 0100 h. Throughout the experiment, birds were hand fed a standard commercial layer diet, and provided with ad libitum access to feed and water. Feed was top dressed with 6 g oyster shell per bird per week from 32 weeks to the end of the trial.

2.3.2 Housing Design

2.3.2.1 Conventional Cage (CONV) (Fig. 2.1)

The CONV treatment consisted of 3 tiers of 14, standard 6-hen laying cages measuring 60 cm wide, 45 cm deep and 40 cm high at the rear. Cages in each tier were divided by installation of a vertical bar partition, yielding 28, 3-hen units per tier. A total of 252 hens were housed in the 84 cages, with each hen having access to 450 cm^2 of floor space.

2.3.2.2 Modified Cage (MOD) (Fig. 2.2)

The modified cage, and the dimensions of the amenities included therein, were based upon design elements from systems including the Get–away cage (Bareham, 1976; Elson 1976), the Bristol Modified cage (Sherwin and Nicol, 1992; 1993) the Edinburgh modified cage (Appleby and Hughes, 1995), the Gleadthorpe cage (Lindberg and Nicol, 1997) and several other principal modified cage studies (Tauson, 1984; Appleby and McRae, 1986; Duncan and Kite, 1989; Appleby, 1990; Appleby and Smith, 1991; Reed and Nicol, 1992; Smith et al., 1993; Hughes, 1993; Appleby et al., 1998; Wall et al., 2002).

Three tiers of 28, standard 6-hen layer cages were modified by addition of an artificial turf-lined, wooden nest box (NB) measuring 24 cm wide, 45 cm deep and 35 cm high at the rear. Nest boxes were placed on the same side of each MOD cage, thereby creating solid cage sides between neighboring units. Two NB entrances measuring 12 cm wide and 15 cm high, and raised 5 cm from the floor, were available, one at the rear of the cage and one at the front. A lightweight door inside each NB was pulled opened or closed 30 minutes before lights were turned on or off, respectively. The door was suspended from two parallel cables at the top of the NB, and could therefore swing inward when in the closed position. This prevented hens from becoming trapped in the NB at door closure, but deterred hens from entering the NB during the night.

A softwood perch of dimensions 5 cm deep, 2.5 cm high and 30 cm long extended from the nest box to the opposite wall of the cage. The perch was positioned 12.5 cm from the back of the cage and 32.5 cm from the front of the cage, at a height of 10 cm above the floor. MOD cages housed 3 hens, providing each of the 252 hens in these systems with 450 cm^2 of floor space and an additional 360 cm^2 of nest space during the day. In both CONV and MOD systems, the cage and NB floors were sloped at an angle of 7°. Manure belts were cleaned twice weekly throughout the trial.

2.3.3 Video recording and behavioural observations

At 35 weeks, video footage from eight randomly selected cages per treatment was recorded in continuous mode beginning at 0630 h. Camera mounts and cables were installed in front of CONV and MOD cages one week prior to filming, to allow hens to adjust to the presence of the equipment. One mount was positioned facing the cage, and for MOD units, a second arm was installed in front of the nest box. Each night prior to filming, black and white closed-circuit video cameras equipped with a 4.0mm lens (Delta Vision, i400LX, Concord, Ontario, Canada) were positioned on the mounts of 2 cages per treatment, and cables were connected to a quad processor system (Delta Vision, DV-Q4CHRTBW, Concord, Ontario, Canada) and VCR (Panasonic 6720A, Mississauga, Ontario, Canada). Filming of the cages was completed over a 4 day period.

Hen preference for use of the nest site in MOD cages was evaluated by noting location of lay on 2 consecutive days every 4 weeks between 20 and 64 weeks. To assess treatment differences in prelaying and nesting behaviour, the frequencies and durations of hen locomotive, agonistic, stereotyped, comfort, resting and ingestive behaviours, as well as the location of these activities was analyzed using 3 approaches, and the software of Observer 5.0 (Noldus Information Technology, The Netherlands, 2002). Firstly, the behaviour of all hens in the 8 CONV and 8 MOD cages (n=24 hens per treatment) was measured by continuous focal sampling for a 1 h period between 06:30 and 07:30. Secondly, video recordings were scanned for oviposition events, and the behaviour of 8 CONV and 8 MOD focal hens who were observed to oviposit between 06:30 and 09:30 h was assessed by continuous observation during this 3 h period. Finally, an interval analysis for these same 16 hens was conducted to examine behaviour during 15 min intervals, beginning 90 min prior to (-90) and extending 30 min beyond oviposition. The definitions of all behaviours recorded are given in Table 2.1. For each of the behavioural states observed, the number of bouts, and their duration was recorded. For event behaviours, the total frequency of events and bouts was noted. Behavioural states, events and bouts were recorded as having ended following pauses of greater than 1 s.

2.3.4 Statistical analysis

All statistical analyses of behavioural data were conducted using procedures of SAS (SAS Institute, 2002) and data are summarized as means ± standard error of the mean. The cage was the experimental unit of measure, and the hens observed were the sample units. After assessment for normality of distribution, data in the form of true frequencies were transformed by addition of 0.5 to each value followed by square root transformation, and percentage values were transformed by arc-sine square root transformation (Martin and Bateson, 1993). Treatment differences in frequency and duration of behavioural elements were assessed using the two-sample t-test. Significance was accepted at $P<0.05$.

2.4 Results

2.4.1 Location of egg laying

On average, when hens were between 20 and 24 weeks of age, 92.1% of eggs from modified cages (n=252 hens) were laid in the nest box (Fig. 2.3). The percentage of nest eggs was lowest at week 20 (72.8%), increased to 91.1% by week 24, and was maintained above 93% for the remainder of the collection period, averaging 93.9% between weeks 24 through 64.

2.4.2 Stereotyped Behaviour and Locomotion

2.4.2.1 One hour interval between 06:30 and 07:30 h

During the 1 h analysis interval between 06:30 and 07:30, continuous behaviour sampling was not possible for one CONV and one MOD focal hen, due to intermittent periods of view obstruction. Behavioural measures from these two hens were therefore omitted from all calculated averages.

As shown in Table 2.2, the frequency (events/h per hen; f) and percent duration (per hen; pd) of bobbing behaviour was higher in CONV cages during this period than in MOD systems (P_f=0.03; P_{pd}=0.01). Mean duration (md) of bobbing activity was also significantly higher in CONV units (md CONV: 6±1 s, md MOD: 2±1 s; P=0.004). Pacing and escape behaviours were minimally observed in either group, however, when pacing behaviour did occur, on average, CONV hens paced for longer periods, as evident from higher mean duration values for CONV hens (md: 8±0 s) than for MOD birds (md: 3±0 s) (P=0.01).

The frequency and percent duration of walking and standing behaviours did not differ between treatments (Table 2.2). Although sitting behaviour occurred more often (P_f =0.0001) and for a greater proportion of the interval (P_{pd}=0.003) in CONV than in MOD, the total frequency of resting activity and the percent of the interval for which resting occurred, as derived from the summation of sitting and perching behaviour (Table 2.2), did not differ between MOD and CONV ($f_{sit + perch}$ MOD: 6±1; f_{sit} CONV: 6±1; $pd_{sit + perch}$ MOD: 26±5; pd_{sit} CONV: 21±4).

2.4.2.2 Three hour interval for hens who oviposited between 06:30 and 09:30

During the 3 h interval between 06:30 and 09:30, in which 8 hens from each treatment were observed to oviposit, bobbing, pacing and escape behaviours occurred significantly more often in CONV cages than in MOD units (Fig. 2.4; $P_{bob}<0.0001$; P_{pace}= 0.02; P_{escape}=0.03). The percentage of the interval during which bobbing occurred (Fig. 2.5) was higher for CONV hens than for MOD hens (P_{pd} =0.0001), as was the percentage duration of escape behaviour (P_{pd}=0.01). The percent duration of pacing (Fig. 2.5) was also higher in CONV cages (P_{pd}=0.01), and the average duration for which pacing occurred was longer for CONV hens (md CONV: 5 s) than for birds in MOD cages (md MOD: 0 s; P_{md}=0.03).

Hens in conventional cages walked more often (P_f=0.01) and stood more frequently (P_f=0.002) than hens in modified cages (Fig. 2.6), and percentage of the 3 h interval spent standing (Fig. 2.7) was also higher in CONV than MOD (P_{pd}=0.004). In MOD cages, neither the frequency of sitting (Fig. 2.6), nor the percentage of the interval spent sitting (Fig. 2.7) differed significantly from sitting behaviour in CONV. However, on average, MOD hens sat for longer durations (md = 204±30 s) than CONV birds (md = 88±16 s; P=0.005). Furthermore, the combined percentage of the 3 h interval spent resting (sitting + perching) (Fig. 2.7) by MOD hens (46.89±5.89) was higher than the sitting percent duration for hens in CONV (20.83±4.94; P=0.003).

2.4.2.3. Fifteen minute interval analysis prior to and post oviposition

As demonstrated in Fig. 2.8, in CONV cages, the frequency of bobbing, escape, walking, standing and sitting behaviours began to increase in the -45 to -30 min intervals prior to egg laying, and for standing, walking and bobbing activity, the rate of increase appeared exponential. Pacing behaviour began to escalate in the -30 to -15 intervals leading to oviposition, and at a more gradual rate. Postlay, the frequency of walking and standing behaviours remained slightly elevated above levels observed during the 90 min interval prior to oviposition, while bobbing, pacing and escape activity ceased.

In contrast, at the beginning of the observation interval, walking and standing occurred at a lower frequency in MOD cages than in CONV cages, and walking, standing and sitting behaviours increased at a less dramatic rate for MOD hens than was observed in CONV (Fig. 2.8). Furthermore, increases in these behaviours in MOD were delayed until the -30 to -15 min intervals prior to oviposition. After oviposition, the frequency of walking and standing by MOD hens dropped below levels observed during the -90 min interval. Bobbing and escape behaviours, which showed only a slight increase in the 30 min interval prior to egg laying, ceased after oviposition.

2.5 Agonistic and Stereotyped Behaviour

2.5.1 One hour interval between 06:30 and 07:30 h

During this interval, the incidence of aggressive pecking was higher for CONV hens than for MOD birds (Table 2.3; P=0.03). Displacement activity did not differ between systems. No differences in the frequency of stereotypic object, feather, or toe pecking were apparent between treatments (Table 2.3), however barb pecking occurred more often in MOD cages (P=0.02).

2.5.2 Three hour interval for hens who oviposited between 06:30 and 09:30

For hens who oviposited, the frequency of aggressive pecking was significantly higher in CONV cages than MOD units (Fig. 2.9; P=0.04), as was the frequency of displacement activity (P=0.04).

Although the frequency of object pecking and feather pecking did not differ between treatments, further examination of the location where these behaviours took place revealed that in MOD cages, 61.39% of object pecking, and 81.9% of feather pecking occurred while hens were in the nest box. The frequency of barb pecking bouts and events was significantly higher in MOD than CONV cages (P=0.03), and toe pecking occurred very infrequently, and only in MOD cages (Fig. 2.9).

2.5.3 Fifteen minute interval analysis prior to and post oviposition

For CONV cages, a marked increase in displacement activity was apparent beginning 30 min prior to oviposition (Fig. 2.10). Concomitant increases in feather and object pecking were also observed during this time. Postlay, displacement behaviour, and feather and object pecking returned to levels observed up to 90 min prior to oviposition, however the frequency of aggressive pecking increased.

From Fig. 2.10, it is apparent that for MOD hens, increases in object and feather pecking during the 3 h analysis began in the 60 min and 30 min intervals prior to oviposition, respectively, and the frequency of both behaviours dropped rapidly post oviposition. Initially, elevations in object and feather pecking were concurrent with an increase in displacement activity (Fig. 2.10), however, whereas pecking activity continued to increase in frequency at -30 min, displacement behaviour declined. Barb and toe pecking occurred solely in the -75 to -60 min, and -15 min intervals prior to oviposition, respectively.

2.6 Comfort

2.6.1 One hour interval between 06:30 and 07:30 h

In the 1 h interval between 06:30 and 07:30, neither the frequency nor percentage of time spent performing neck extension behaviour differed between treatments (Table 2.4). Although the total number of times hens preened and the total percent duration of preening did not differ between groups, CONV hens spent a greater percentage of the 1 h interval preening their back (P_{pd}=0.05) and breast (P_{pd}=0.01) regions than MOD hens, and also preened their breast region more frequently (P_f=0.002).

No differences were apparent in the frequency of, or percentage time spent ground scratching, or performing any of comfort feather ruffling, head scratching, head shaking, or wing/leg stretching (Table 2.4).

2.6.2 Three hour interval for hens who oviposited between 06:30 and 09:30

During the 3 h period in which hens oviposited, neck extension behaviour did not differ in frequency (Fig. 2.11) or percent duration (Fig. 2.12) between treatments. Ground scratching activity occurred more often (Fig. 2.11) in CONV cages than in MOD units (P=0.05), and the percent duration of ground scratching was also higher for CONV hens (Fig. 12; P=0.05). Although the frequency of feather ruffling did not differ between CONV and MOD hens (Fig. 2.11), birds in MOD cages performed this comfort behaviour for a longer mean duration (MOD (3±0 s); CONV (2±0 s) (P=0.04) and percentage of the interval (Fig. 2.12; P=0.02).

No additional differences in frequency or percent duration of comfort head scratching, head shaking, wing/leg stretching or total preening activity were observed between CONV and MOD cages. However, closer examination of preening of individual body regions indicates that preening in the tail region was performed more often (Fig. 2.13; P_f=0.005), and for a larger percent duration of the interval (Fig. 2.14; P_{pd}=0.01) by MOD hens.

2.6.3 Fifteen minute interval analysis prior to and post oviposition

For both CONV and MOD hens, the frequency of neck extension behaviour began to increase slightly in the -45 to -30 min intervals prior to oviposition, and declined post egg laying (Fig. 2.15). Total preening frequency increased rapidly for CONV hens until 45 min prior to egg laying, then dropped markedly until oviposition, and subsequently began to increase at a gradual rate. In contrast, MOD hens, who also showed a peak in preening at approximately -60 min, continued to preen at a higher frequency than CONV hens through to oviposition, and rapidly increased the incidence of preening postlay.

For CONV hens, the frequency of ground scratching behaviour began to increase dramatically in the 45 min prior to egg laying, remained elevated through oviposition, and declined rapidly thereafter. Ground scratching activity remained fairly constant for MOD hens, showing a slight increase in frequency immediately after oviposition.

A comparison of the frequency of comfort preening for individual body regions (Fig. 2.16) reveals a very distinct pattern of grooming in relation to oviposition for CONV hens. Preening in all regions increased between -75 and -60 min prior to oviposition, peaked during the -60 to -45 min interval, and was followed by a rapid decline in preening activity, which ceased through oviposition and began to gradually increase postlay.

For hens in MOD cages, a less definitive activity pattern was apparent (Fig. 2.16). Preening levels peaked earlier, at approximately -60 min, but remained elevated above CONV levels, and fluctuated throughout the observation period. With the exception of preening in the tail region, preening in all other regions declined briefly in the 15 min interval leading to oviposition. Post egg laying, preening activity increased rapidly for MOD hens.

2.7 Rest and Ingestion

2.7.1 One hour interval between 06:30 and 07:30 h

During this observation period, MOD hens engaged in dozing behaviour more frequently (P=0.003), and in dozing and sleeping behaviour for a greater proportion of the time (P_{doze}=0.001; P_{sleep}=0.05) than CONV hens (Table 2.5).

Eating behaviour did not differ in frequency or duration between groups (Table 2.5). MOD hens drank more frequently than CONV hens during this period (P=0.01), however, the overall percentage of time spent drinking, did not differ between treatments.

2.7.2 Three hour interval for hens who oviposited between 06:30 and 09:30

Whereas hens in CONV cages were not observed to sleep or doze during this 3 h period (Fig. 2.15), MOD birds spent time sleeping and dozing, primarily in the nest box, but also in the cage or on the perch. Conversely, CONV hens spent a greater proportion of the interval awake and observant (P=0.005). For dozing, the difference in behavioural expression was also significant (P=0.001).

Although hens in CONV cages ate more frequently than hens in MOD cages (f CONV: 132±13.66; f MOD: 94±10.05; P=0.04), neither the percentage of the interval spent feeding (Fig. 2.17), nor the mean duration of feeding behaviour (md CONV: 20±4 s; md MOD: 20±3 s) differed between treatments. Frequency (f CONV: 30±5.89; f MOD: 38±10.08; P=0.23) and percent duration (Fig. 2.17) of drinking bouts also did not differ between the two groups.

2.7.3 Fifteen minute interval analysis prior to and post oviposition

Sleeping and dozing behaviour by MOD hens was observed in the hour prior to egg laying, and dozing resumed immediately after oviposition (Fig. 2.18).

During the 15 min intervals surrounding oviposition, patterns of eating behaviour showed similar trends for CONV and MOD hens (Fig. 2.18). In both systems, feeding activity began to decline in frequency as oviposition approached, then increased dramatically immediately post lay, and declined again in the subsequent interval. CONV hens showed a sudden increase in feeding activity approximately 15 min prior to oviposition, and although less frequent, drinking patterns followed a parallel pattern for these birds (Fig. 2.18). Notably, for CONV hens, ground scratching behaviour remained elevated in the 15 minute interval prior to oviposition (Fig. 2.15), despite the sharp decline in feeding activity at this time (Fig. 2.18).

Initially, for MOD hens, a decline in drinking behaviour occurred concomitantly with reduced feeding activity. However in the -30 and -15 min intervals, hens in MOD cages ceased drinking activity, and resumed the behaviour in the 15 min prior to oviposition.

2.8 Locations where time was spent by CONV and MOD hens during the 1 h interval between 06:30 and 07:30, and the 3 h interval surrounding oviposition

During the period from 06:30 to 07:30, in which all hens from 8 cages per treatment were observed, (Fig. 2.19), MOD hens spent the majority of their time on the cage floor (58.3%) and on the perch (32.7%), using the nest box only 8.4% of the time, and stopping on the nest box doorframe for only 0.6% of the interval. In contrast, during the 3 h analysis period, in which 8 hens from each treatment were observed to oviposit (Fig. 2.20), MOD hens divided their time between the cage (39.2%), the perch (26.3%), the nest box (33.0%), and the nest box door frame (1.5%).

2.9 Discussion

2.9.1 Location of egg laying

In the current study, consistently high use of the nest box by MOD hens suggests that not only was a suitable nesting environment created in MOD (Appleby and Smith, 1991), but that hens clearly preferred to lay their eggs in this nest site, rather than on the cage floor (Cooper and Albentosa, 2003). Since hens were first transferred to cages systems at 19 weeks of age, the somewhat lower incidence of nest use at week 20 likely reflects an initial discovery period, during which hens learned to gain entrance to the nest box through the slightly raised doorway.

2.9.2 Stereotyped Behaviour and Locomotion

Bobbing, escape and pacing movements are characterized as stereotyped behaviours performed by hens that are experiencing frustration (Duncan, 1970; Wiepkema, 1985; Webster and Hurnik, 1990b). In the present study, the increased frequency and duration of bobbing activity, as well as the greater mean duration of pacing behaviour observed for CONV hens during the 1 h early morning period suggests that overall, hens in CONV experienced greater frustration than hens in MOD. From both the 3 h observation period of hens who oviposited and from the interval analysis, it is evident that this frustration was a result of the inability of CONV hens to express normal nesting behaviour. In the absence of a nest site, hens in CONV not only exhibited an increased incidence of bobbing, escaping and pacing behaviours, but were also engaged in these behaviours for a greater amount of time than MOD hens. Furthermore, as evident from the interval analysis, the elevation in frequency of these activities occurred at a very rapid rate in the minutes leading to oviposition, whereas postlay, bobbing, escaping and pacing movements ceased, suggesting that CONV hens were becoming increasingly frustrated prior to oviposition. Previous studies have also attributed increases in these activities during the prelay period to frustration resulting from the absence of a nest site in cage systems (Brantas, 1980; Sherwin and Nicol, 1993).

When caged hens are unable to access a laying nest, frustrated prelaying behaviour is further expressed through restlessness. Indicators of disquiet include pacing and escape movements (Brantas, 1980), as observed by CONV hens in the current study, as well as changes to sitting behaviour (Meijsser and Hughes, 1989), and increased frequency of activity shifts (Hansen, 1994). No differences in walking, standing or resting behaviour were apparent between CONV and MOD during the 1 h early-morning analysis period in the current study, suggesting that hens in both systems were equally active at this time. However, during the 3 h observation period in which hens were observed to oviposit, hens in CONV walked about the cage more frequently than MOD hens, stood more often and for longer durations, and rested for shorter periods of time. Prelay activity for CONV hens therefore consisted of fewer, shorter rest periods which were interrupted by frequent changes in activity, suggesting that in the absence of a nest site, hens in CONV experienced greater restlessness, and consequent greater frustration than MOD hens. Yue and Duncan (2003), who observed increased frustrated pacing by hens denied access to a nest, proposed that presence of a nest site stimulated the sitting component of nesting behaviour, and Meijsser and Hughes (1989) suggested that caged hens without access to a laying nest extended their search for a nest site at the expense of sitting.

Results from the pre- and post-lay interval analysis in the present study provide additional evidence that hens in CONV were more restless than MOD hens, and that this disquiet resulted from the absence of a nest site in CONV. In both systems, activity levels increased prior to oviposition, peaked during the egg laying interval, and declined rapidly thereafter. For CONV hens however, stereotyped and locomotive behaviours were elevated above MOD levels at the beginning of the interval period, escalated earlier and at a more rapid rate, and remained elevated above MOD levels post oviposition. In the absence of a nest site, CONV hens therefore not only experienced increased frustration in the time leading up to egg laying, but also recovered less quickly from this stressful event. The slight increase in standing and walking activity that occurred concomitantly with increased sitting in MOD can be attributed to the fact that hens in MOD often stood up and walked around the nest box to reposition themselves or to preen, or left the nest box briefly to feed or drink. Sherwin and Nicol (1993) describe similar behaviours for hens in modified cages.

2.9.3 Agonistic and Stereotyped Behaviour

Indices of aggression, including pecking to the head and neck region (Duncan and Wood-Gush, 1971) and displacement activity (Stone, 1984), have been shown to increase when hens are frustrated. During the 1 h interval analysis of the present study, the incidence of aggressive pecking was higher in CONV than in MOD units. Aggressive pecking was also higher for CONV hens experiencing prelay than for MOD hens, as was displacement activity, which had not differed between treatments during the 1 h analysis period. These findings support the above intimation that in general, frustration was higher in CONV and increased in response to the inability of CONV hens to express normal nesting behaviour. Notably, whereas aggressive pecking by CONV hens stopped abruptly in the interval prior to oviposition and increased rapidly immediately after egg laying, the frequency of displacement activity was very high during the prelay intervals, but ceased after oviposition. Furthermore, the increase in displacement activity occurred concomitantly with a rise in locomotive behaviours, suggesting that as CONV hens became increasingly restless in their search for a nest site, their agonistic behaviour shifted from aggressive pecking to displacement of cagemates whose position in the cage impeded their movement. Hughes (1979) also observed reduced incidence of aggressive pecks and threats in caged birds prior to oviposition, and Webster and Hurnik (1990) noted an association between walking and bobbing behaviours and physical displacement prior to laying. Post oviposition, as nest searching and restless activity ceased, CONV hens discontinued displacement activity but resumed frustrated aggressive pecking, also suggesting that for hens without access to a nest site, distress remained elevated postlay.

Stereotyped behaviours such as object and feather pecking also occur when individuals are frustrated by inadequacies in their housing environment (Hurnik et al., 1985; Broom, 1991). Given the elevated frustration observed for CONV hens in the current study, it might therefore be expected that the incidence of object and feather pecking bouts would be higher in CONV than in MOD. No differences in either pecking activity were observed between treatments during the 1 h general analysis period, or the 3 h interval in which hens oviposited. However, for hens who laid their eggs in MOD systems, approximately 61% of object pecking and 82% of feather pecking bouts took place in the nest box, suggesting that for MOD hens, these motor patterns were related to nesting behaviour. Grasp-pull and particle pecking inside the nest have previously been associated with nest site inspection (Sherwin and Nicol, 1992) and nest building (Sherwin and Nicol, 1993), and it is not uncommon for domestic hens to gather loose materials such as feathers to add to the nest perimeter (Duncan and Kite, 1989). It is also possible that feather pecking in MOD nest sites may have been related to competition for nest space. Indeed, hens in MOD occasionally attempted to displace cagemates from the nest, and Appleby and Smith (1991) previously observed that hens who were unsuccessful in supplanting other hens from the nest site resorted to pecking and trampling behaviour. However, whereas object and feather pecking both increased synchronously with displacement activity in CONV, in MOD object and feather pecking increased with declining displacement activity prior to egg laying, and both pecking behaviours ceased after oviposition. Therefore, whereas feather and object pecking in CONV likely occurred in response to frustration, in MOD these behaviours were likely associated with nesting activity.

Barb pecking has been described as a gentle form of feather pecking that may develop into a stereotyped behaviour, but does not cause harm to, and is therefore ignored by the recipient (Savory, 1995). The activity, which has been observed to occur more frequently under developmental conditions of low light intensity where bird visibility is reduced, is thought to reflect beak-related exploration of the environment (Kjaer and Vestergaard, 1999). Chow and Hogan (2005) have also found that when chicks are deprived of an exploratory-rich environment, they are more inclined to perform gentle pecking, perhaps as a redirection of exploratory behaviour. In the present study, barb pecking was observed to occur more frequently in MOD than in CONV, both in general, and specifically during the prelay period. Although it might be expected that hens in CONV, who experienced less environmental stimulation than MOD hens, would be more inclined to direct exploratory pecking toward conspecifics, it is also possible that this investigative activity was more prevalent in MOD hens because they were expressing normal prelaying behaviour. Investigatory behaviour is typical of hens at the onset of prelay (Wood-Gush, 1975). Notably, barb pecking occurred very early on in the prelay period and not at all in the nest box, perhaps suggesting that MOD hens began this exploratory behaviour in the cage but found greater stimulation from pecking at or in the nest. The infrequent occurrence of toe pecking in MOD, but not in CONV, further supports that exploratory behaviour was encouraged by the nest site, but that objects in the nest ultimately provided a greater stimulus for pecking. Vestergaard et al. (1997), who noted that hens housed in wire-floored cages decreased their frequency of toe pecking when provided with access to sand, also proposed that hens were redirecting their pecks at the stronger stimulus.

2.9.4 Comfort

Neck extension is also an exploratory behavioural pattern (Webster and Hurnik, 1989), and is observed during the prelay period as a component of nest site inspection (Sherwin and Nicol, 1993). Since neither the frequency nor the duration of neck extension differed between CONV and MOD hens during any of the periods observed in the current study, it is possible that the behaviour was not influenced by the presence or absence of a nest site. Sherwin and Nicol (1992) for example, found that the incidence of nest inspections in caged hens was unrelated to egg laying behaviour. Alternatively, it is possible that hens in CONV and MOD were motivated to perform the behaviour for different reasons. Since increased nest inspections have been linked to extended searching activity (Hughes and Meijsser, 1989), CONV hens may have repeatedly performed the behaviour in their unsuccessful attempts to locate a suitable nest site. In contrast, for MOD hens, the presence of the nest box itself may have stimulated nest searching activity (Cooper and Appleby, 1996b). The increasing occurrence of neck extension behaviour prior to oviposition for both groups, and the subsequent decline post egg laying, supports the latter explanation.

Ground scratching behaviour is typically performed by hens during foraging, and to a lesser extent, is also considered an expression of frustration (Hurnik et al. 1985). In the present study the behaviour was directed almost exclusively at the egg guard, but also occurred in the nest box and on the cage floor. Similar frequency and duration of ground scratching between CONV and MOD hens during the 1 h analysis period, despite increased frustration in CONV, suggests that the behaviour was associated with feeding during this time. In contrast, during the 3 h analysis period of hens who oviposited, ground scratching often appeared stereotyped and unrelated to feeding activity when performed by CONV hens. Indeed, birds in CONV dramatically increased ground scratching as oviposition approached and feeding behaviour declined, yet performed similar levels to MOD hens postlay, when feeding activity was increasing. These findings suggest that ground scratching behaviour by CONV hens during the prelay period was an expression of frustration resulting from the inability of hens to express normal nesting behaviour.

The absence of differences in feather ruffling, head scratching, head shaking and wing/leg stretching frequencies between CONV and MOD during both the 1 h analysis period and the 3 h interval in which hens oviposited was somewhat unexpected, given that CONV hens were clearly more frustrated than MOD hens, and therefore less likely to express indices of comfort. Tanaka and Hurnik (1991; 1992), who observed elevated levels of the above behaviours for birds housed in aviary systems as compared to cage-housed hens, attributed these differences to a higher level of comfort experienced by birds in an aviary environment. The authors, however, further attributed the rare occurrence of comfort behaviours in cage systems to a lack of space for movement. Nicol (1987) compared hens housed at three cage floor area allowances and also observed a reduction in comfort activities with increasing space restriction. Notably, during the prelay period of the present study, the mean duration and overall percentage of time spent feather ruffling, a behaviour whose expression has been shown to be less affected by reductions in floor space (Dawkins and Hardie, 1989), were significantly higher for MOD hens, even though the number of times the behaviour was performed did not differ between groups. This suggests that when birds in MOD performed feather ruffling, they were able to fully express the motor pattern, whereas for CONV hens, the behaviour was functionally incomplete, and may therefore have been displaced (Tinbergen, 1952).

Frustrated hens may also exhibit displacement preening, which is characterized by shortened bout durations and disproportionate grooming of easily-accessible areas of the plumage (Duncan and Wood-Gush, 1972). In the present study, preening behaviour was prevalent in both CONV and MOD, and no differences in frequency or duration of total preening activity were apparent between the two groups. However, increased preening of the back and breast regions by CONV hens during the 1h observation period, and lower frequency and duration of tail preening by CONV hens who oviposited suggests that preening behaviour for hens without access to a nest site may have been displaced. Furthermore, the increase in preening activity by CONV hens was rapid and concentrated within a short period of time, and the subsequent drop in preening coincided with increases in frustrated locomotive and stereotyped behaviours, and oviposition. Any comfort derived from the behaviour would therefore likely have been short-lived.

In contrast, preening activity in MOD was more indicative of comfort grooming. Hens maintained elevated preening behaviour over all areas of the plumage throughout the egg laying period, were often observed to groom while sitting in the nest, and post oviposition quickly resumed preening. These findings provide additional evidence that MOD hens were more at ease during the prelay periods than CONV hens, and also recovered from the stress of oviposition more readily.

2.9.5 Ingestion and rest

Overall, whereas hens in CONV spent little to no time sleeping or dozing, MOD hens engaged in both resting behaviours throughout the observation periods, and even during the interval in which they oviposited. Meijsser and Hughes (1989) also observed that hens in cages without nest sites did not sleep during the prelay period. It has been suggested that in extensive housing systems, sleep during this time may be of little importance to the hen (Sherwin and Nicol, 1993). However, resting behaviour by MOD hens in the present study indicates that when caged hens are able to express normal nesting activity, they experience greater ease and comfort and are therefore able to relax in their environment, both before and after oviposition. In contrast, caged hens deprived of nest sites experience frustration and restlessness. For caged hens then, sleeping and dozing during the prelay period may be of great importance to hen welfare.

Few differences were observed between eating and drinking behaviour either during the 1 h assessment period, or during the pre- and post-lay observation intervals, suggesting that in the present cage study, ingestive tendencies were not a clear indicator of hen welfare. Meissjer and Hughes (1989) suggest that excessive eating in the absence of a nest site may reflect displaced activity resulting from hen frustration. CONV hens did exhibit a brief increase in feeding activity approximately 15 min prior to oviposition, perhaps indicating frustration at this time. However frustrated feeding bouts are typically fragmented and of shorter duration (Duncan, 1970), and in the present study, the mean duration of feeding was not different between CONV and MOD.

2.9.6 Locations where time was spent by CONV and MOD hens

Minimal use of the nest box during the 1 h early morning observation period and increased nest use during the period in which hens oviposited provides additional evidence that hens regarded this amenity as a distinct and functional nesting environment. This finding reiterates the importance of providing a specific and separate area for nesting, in addition to the allocated cage floor space. Appleby (1990) determined that incorporating a nest site within an existing area of the cage resulted in disturbed nesting behaviour and limited hens to a smaller cage area throughout the remainder of the day, since hens would not use nest sites to perform other behaviours. The self-imposed restricted use of the nest site by MOD hens in the current study minimized soiling therein, thereby contributing to the quality of nest eggs. Hens perched very infrequently on the nest box door frame, which also minimized soiling in the nest box. Notably, perch use by MOD hens was consistently high, and contributed to improved foot and claw condition (Chapter 5), greater leg bone strength (Jendral et al., 2008), improved use of the 3 dimensional space of the cage, and facilitated movement within the cage.

2.9.7 Welfare and Economic implications

The frustrated behaviour exhibited by caged hens deprived of access to a nest site has both welfare and economic implications. Frustrated hens experience distress, which reduces hen well-being (Brantas, 1980), and may cause birds to delay oviposition (Hughes et al., 1986). When nesting is delayed, eggs are retained in the shell gland and hens continue to deposit calcium on the cuticle surface (Watt and Solomon, 1988). This additional calcium deposition may change the colour and texture of the shell thereby impacting egg quality and value, and may also necessitate continued mobilization of calcium from skeletal reserves, although additional calcium loss may be negligible (Yue and Duncan, 2003).

Increased pacing, escaping, bobbing, standing and walking activity by conventionally-caged hens also requires additional energy expenditure (Wood-Gush and Gilbert, 1969), particularly if the restless behaviour extends over a lengthy period, as was observed by CONV hens in the current study. The net daily energy expenditure for nest-deprived hens may therefore impact feed conversion efficiency over the course of the laying cycle.

Injury sustained from frustrated aggressive pecking and displacement activity causes pain and suffering, and may impact hen productivity (Savory, 1995). Plumage loss resulting from feather pecking by frustrated hens may also necessitate increased feed consumption to balance heat loss (Tauson and Svenson, 1980).

2.9.8 Conclusions

This study emphasizes the importance of providing nesting facilities for caged hens, and demonstrates a viable solution for incorporating nests in conventional cages. The results, which clearly indicate that hens experience daily frustration, discomfort and increased aggression when unable to perform natural nesting behaviour, provide compelling evidence for the improvement of hen welfare by the addition of a nest box to conventional cages, a modification that allows producers to make use of existing cage capital and to maintain the benefits of cage systems. The findings from this study have implications for the adoption of modified cage housing practices in North America to promote the welfare and productivity of caged hens.

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2.11 Tables and Figures

Table 2.1 Ethogram of behavioural patterns measured in this study.

Behaviour	Description	References
Stereotyped Behaviour and Locomotion		
*Pace	Quick and repeated back and forward walking along any side of the cage	Mills and Wood-Gush, 1985; Yue and Duncan, 2003
*Escape	Bird repeatedly steps up through the bars of the cage in an attempt to escape from the enclosure. Also described as head out.	Wiepkema, 1985
Walk	Taking more than one step anywhere in the cage system.	
Stand	Hen changes position from sitting, walking or perching, and stands on her feet with her legs extended, anywhere in the cage system.	Duncan et al., 1989; Webster and Hurnik, 1990b
Sit	Sitting or lying down on the floor of the cage or nest box.	Webster and Hurnik, 1990b
Perch	Resting on the perch (sitting or lying)	Hurnik et al., 1985; Hansen, 1994
Agonistic and (Other) Stereotyped Behaviour		
**Aggressive peck	Forceful pecks directed at the head and/or comb of conspecifics.	Savory, 1995; Kjaer et al., 2001
Displace	When a hen uses force to supplant a cagemate, either by pushing the cagemate directly or by inserting its head and thorax underneath the cagemate and lifting	Webster and Hurnik, 1990b
**Object peck	Pecking at, or use of the beak to grasp and pull at any feature of the environment other than the feeder, drinker, another bird or oneself.	Webster and Hurnik, 1990b; Sherwin and Nicol, 1993
**Feather peck/pull	Forceful use of the beak to peck at and/or grasp and pull the feathers of a conspecific's or one's own plumage, with or without feather removal.	Tanaka and Hurnik, 1991; Savory, 1995; Kjaer et al., 2001
**Barb (gentle) peck	Pecks directed at the feather tips of a conspecific. Is gentler in nature than severe feather pecking or pulling and may appear stereotyped.	Savory, 1995; Kjaer and Vestergaard, 1999
**Toe peck	Repetitive gentle pecking at one's own toes or legs.	Webster and Hurnik, 1990b; Vestergaard et al., 1997
Bob	Repetitive raising and lowering of the head, neck and often the thorax. Often associated with pacing.	Webster and Hurnik, 1990b

Comfort Behaviour		
Neck extension	Extending the head and neck away from the body whilst the body remains motionless.	Webster and Hurnik, 1989; Cooper and Appleby, 1996b
Preen	Using the beak to self-manipulate feathers, or skin, by combing, stroking, nibbling or gentle pecking. Body regions targeted include: i) back (shoulders and upper back); ii) belly; iii) breast (breast and throat); iv) inside wing (under wing coverts and flanks); v) outside wing (front edge of wing coverts and pinion); vi) tail (tail, rump, vent and uropygial gland)	Webster and Hurnik, 1990b; Duncan and Wood-Gush, 1972; Blokhuis, 1984
Ground scratch	Scratching movements in the form of backward strokes with one leg, usually repeated several times. May be followed by the other leg. Hen may be standing or sitting. Scratching may be directed at the ground or at the egg guard.	Black and Hughes, 1974; Nicol, 1987
Feather ruffle	The hen extends her neck, raises and fluffs her feathers, and shakes her whole body.	Hurnik et al., 1985; Mishra et al., 2005
Head scratch	Hen scratches her lowered head and bill with her foot by passing her leg upwards and forwards underneath her wing.	Black and Hughes, 1974; Nicol, 1987
Head shake	Head held normally and moved rapidly and repeatedly from side to side. Not recorded during feeding or drinking. Also described as headflicking.	Black and Hughes, 1974; Mills and Wood-Gush, 1985; Hughes 1983.
Wing/leg stretch	Unilateral backward and downward or sideways extension of the wing, generally together with the leg on the same side.	Black and Hughes, 1974; Nicol, 1987
Rest Behaviour		
Sleep	Eyes closed and feathers slightly fluffed. Head tucked into feathers above the wing base or behind the wing. Wings may be drooping. Hen may be sitting, perching or standing.	Blokhuis, 1984
Doze	Eyes closed or slowly opening and closing, and feathers slightly fluffed. Neck is pulled back and head is drawn into the contour feathers of the body but may be drooping. Hen may be sitting, perching or standing.	Blokhuis, 1984; Duncan et al., 1989
Observe	Eyes open, hen is observing	
Ingestive Behaviour		
Eat	All activity involving feed manipulation including consumption, pecking, probing	Duncan et al., 1989; Webster and Hurnik,

	and flicking	1990b
Drink	All pecking at the nipple drinker	Mills and Wood-Gush, 1985; Duncan et al., 1989
Location		
Cage	Both feet in the cage	
Nest box	Both feet in the nest box	
Perch	Both feet on the perch	
Nest box door frame	Both feet on the nest box door frame	

Behaviours within each category were mutually exclusive.

*Stereotyped behaviour but mutually exclusive with other locomotory behaviours

**Bouts and events recorded

Table 2.2 Frequency (± SEM) and percent duration (± SEM) of stereotyped and locomotive behaviour of CONV and MOD hens during the 1 h observation period.

	Frequency				**Percent Duration**			
	CONV[a]	**MOD**[b]	**t value**	**P value**	**CONV**[a]	**MOD**[b]	**t value**	**P value**
Bob	2 (0.72)	1 (0.22)	2.36	0.0250	0.42 (0.15)	0.04 (0.02)	2.82	0.01
Pace	0 (0.07)	0 (0.09)	0.56	0.5815	0.03 (0.02)	0.01 (0.01)	0.91	0.37
Escape	2 (0.90)	1 (0.27)	1.05	0.2993	0.20 (0.07)	0.12 (0.05)	0.56	0.58
Walk	22 (3.50)	17 (1.91)	1.23	0.2246	2.05 (0.29)	1.65 (0.19)	1.23	0.23
Stand	31 (3.90)	24 (1.95)	1.49	0.1435	79.22 (3.49)	72.43 (4.55)	0.66	0.51
Sit	6 (0.72)	2 (0.51)	4.65	<0.0001	20.88 (3.64)	9.10 (3.73)	3.13	0.003
Perch	-	4 (0.58)	-	-	-	16.69 (3.28)	-	-

[a] Hens from conventional cages (n=23 hens)

[b] Hens from modified cages (n=23)

Table 2.3 Frequency (± SEM) of agonistic and stereotyped behaviour of CONV and MOD hens during the 1 h observation period.

	CONV[a]	MOD[b]	t value	P value
Agonistic				
Aggressive Peck	4 (1.33)	1 (0.18)	2.23	0.03
Displace	3 (0.69)	2 (0.54)	1.76	0.09
Stereotyped				
Object Peck	14 (3.79)	12 (2.43)	0.17	0.87
Feather Peck	2 (1.19)	1 (0.21)	0.16	0.87
Barb Peck	1 (0.26)	2 (0.70)	2.52	0.02
Toe Peck	1 (0.53)	4 (1.89)	1.72	0.10

[a] Hens from conventional cages (n=23 hens)

[b] Hens from modified cages (n=23)

Table 2.4 Frequency (± SEM) and percent duration (± SEM) of comfort behaviour by CONV and MOD hens during the 1 h observation period.

	Frequency				Percent Duration			
	CONV[a]	**MOD[b]**	**t value**	**P value**	**CONV[a]**	**MOD[b]**	**t value**	**P value**
Neck Extension	3 (0.70)	4 (0.91)	1.13	0.2635	0.48 (0.14)	0.53 (0.14)	0.81	0.4230
Preen								
Total	52 (7.82)	40 (7.71)	1.25	0.2166	11.77 (2.16)	9.54 (1.94)	0.93	0.36
Back	18 (2.71)	13 (1.94)	1.51	0.1374	4.60 (0.82)	2.62 (0.47)	2.04	0.05
Breast	15 (2.19)	7 (1.35)	3.30	0.0020	2.95 (0.69)	1.19 (0.28)	2.90	0.01
Belly	6 (1.15)	6 (1.35)	0.31	0.7562	1.21 (0.30)	1.21 (0.25)	0.09	0.93
Inside Wing	3 (0.90)	3 (0.72)	0.08	0.9358	0.60 (0.29)	0.65 (0.20)	0.49	0.63
Outside Wing	6 (1.33)	4 (1.14)	0.96	0.3426	1.25 (0.34)	0.82 (0.30)	0.96	0.34
Tail	5 (0.93)	7 (2.09)	0.61	0.5475	1.16 (0.23)	3.05 (0.83)	1.52	0.14
Ground scratch	39 (5.21)	34 (3.71)	0.59	0.5604	2.59 (0.40)	2.47 (0.59)	0.41	0.68
Feather Ruffle	1 (0.19)	1 (0.20)	1.11	0.2733	0.04 (0.01)	0.06 (0.02)	1.14	0.26
Head Scratch	2 (0.16)	1 (0.29)	1.77	0.0850	0.04 (0.01)	0.09 (0.02)	1.45	0.15
Head Shake	7 (1.02)	7 (1.03)	0.26	0.7943	0.07 (0.02)	0.11 (0.03)	1.26	0.21
Wing/Leg Stretch	1 (0.25)	1 (0.23)	0.47	0.6415	0.48 (0.40)	0.10 (0.03)	0.58	0.56

[a] Hens from conventional cages (n=23 hens)

[b] Hens from modified cages (n=23)

Table 2.5 Frequency (± SEM) and percent duration (± SEM) of rest and ingestive behaviour by CONV and MOD hens during the 1 h observation period.

	Frequency				**Percent Duration**			
	CONV[a]	**MOD**[b]	**t value**	**P value**	**CONV**[a]	**MOD**[b]	**t value**	**P value**
Rest								
Sleep	0 (0.00)	1 (0.34)	1.98	0.0600	0.00 (0.00)	1.59 (0.86)	2.05	0.05
Doze	0 (0.06)	5 (1.66)	3.23	0.0034	0.15 (0.15)	3.13 (0.92)	3.76	0.001
Observe	1 (0.00)	6 (1.64)	2.95	0.0067	99.85 (0.15)	95.28 (1.51)	3.62	0.001
Ingestion								
Eat	40 (4.48)	37 (3.97)	0.52	0.6024	23.51 (2.58)	28.94 (3.67)	1.10	0.28
Drink	9 (1.87)	20 (3.18)	2.67	0.0109	2.32 (0.71)	2.92 (0.50)	1.11	0.27

[a] Hens from conventional cages (n=23 hens)

[b] Hens from modified cages (n=23)

Figure 2.1 The conventional battery cage (CONV).

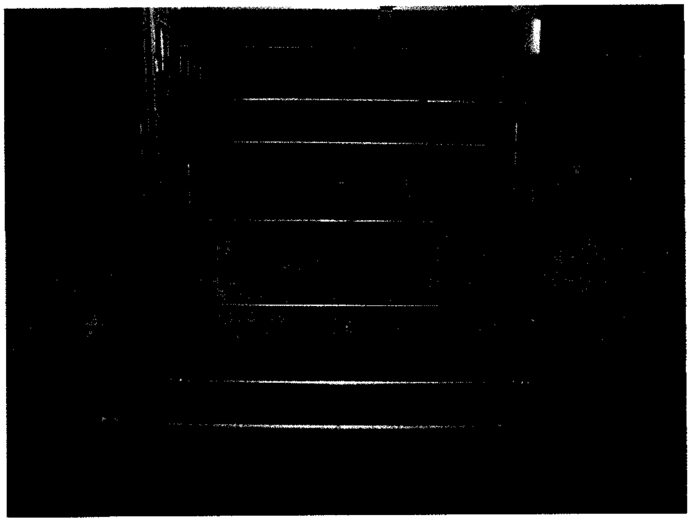


Figure 2.2 The modified battery cage (MOD).

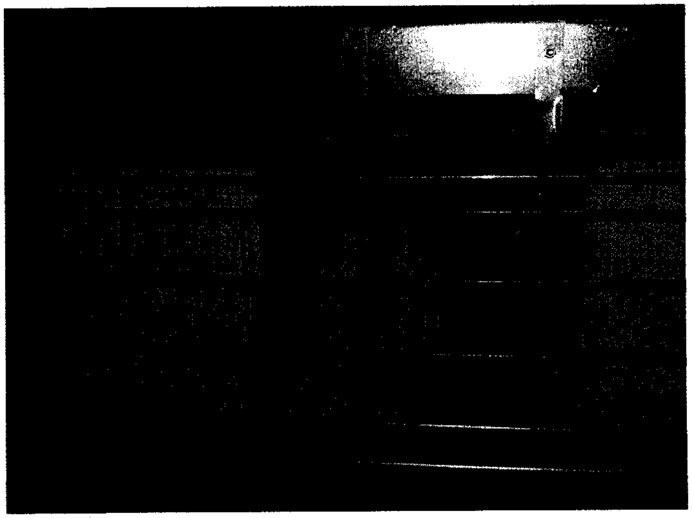


Figure 2.3 Percentage of eggs laid (mean ± SEM) in the nest box in MOD cages between 20 and 64 weeks.

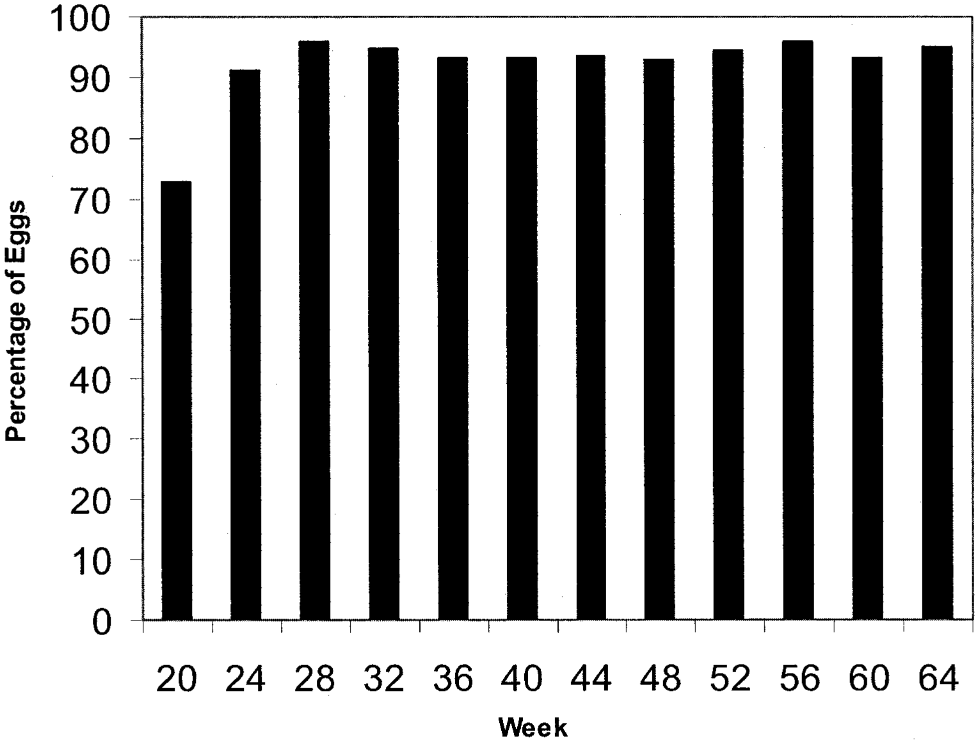


Figure 2.4 Frequency (mean ± SEM) of stereotyped behaviour of CONV and MOD hens during the 3 h interval in which hens oviposited *(*P <0.05; ***P <0.001).*

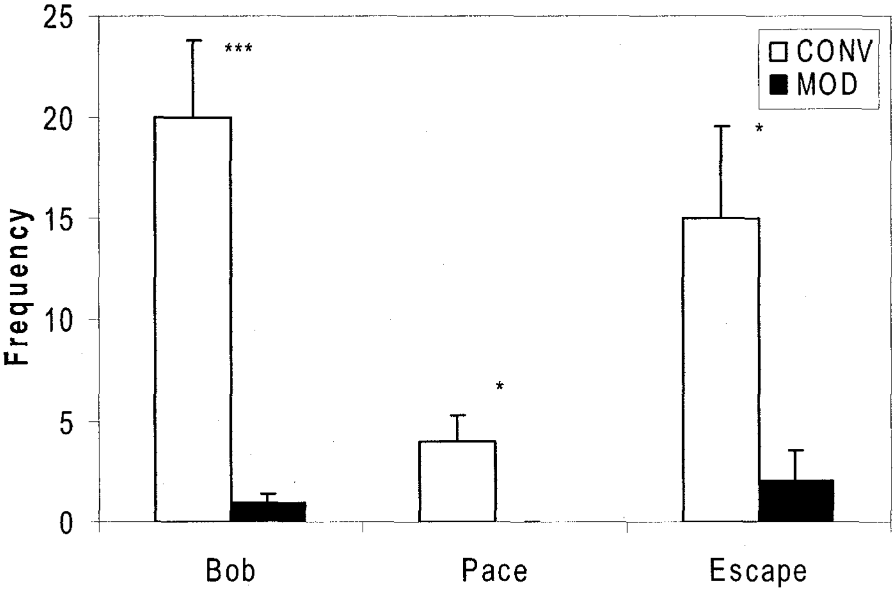


Figure 2.5 Percent duration (mean ± SEM) of stereotyped behaviour of CONV and MOD hens during the 3 h interval in which hens oviposited *(*P <0.05; **P <0.01).*

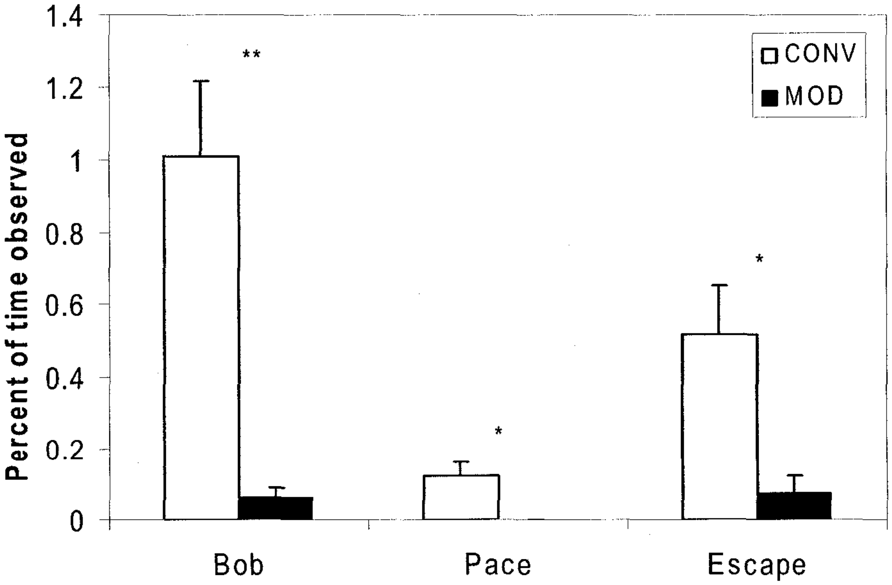


Figure 2.6 Frequency (mean ± SEM) locomotive behaviour of CONV and MOD hens during the 3 h interval in which hens oviposited *(*P <0.05; **P <0.01)*.

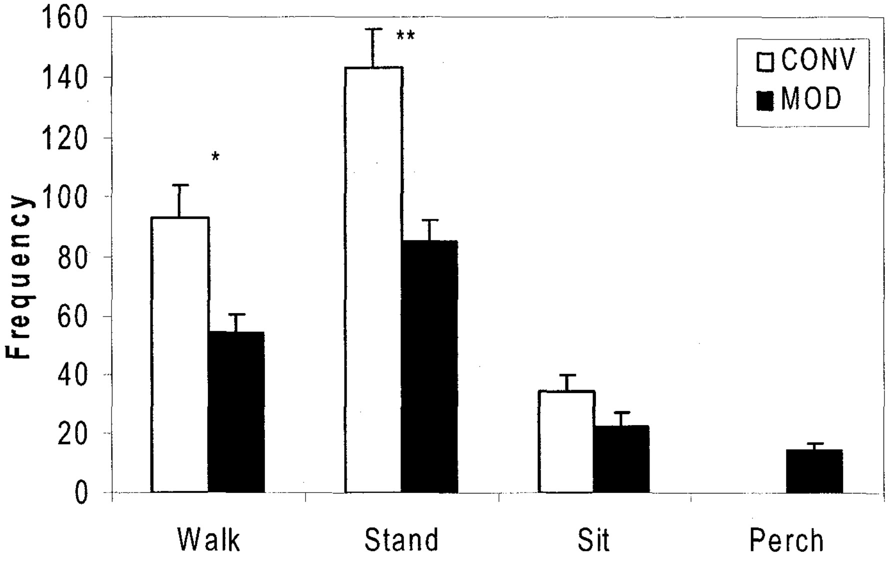


Figure 2.7 Percent duration (mean ± SEM) of locomotive behaviour of CONV and MOD hens during the 3 h interval in which hens oviposited *(*P <0.05; **P <0.01)*.

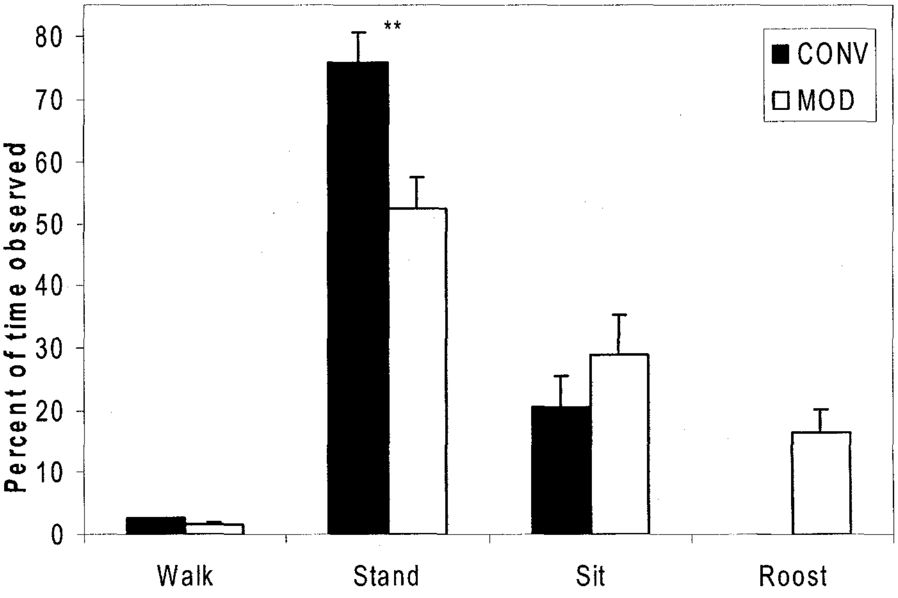


Figure 2.8 Frequency of stereotyped and locomotive behaviour of CONV and MOD hens during 15 min intervals beginning 90 min prior to oviposition and ending 30 min post oviposition.

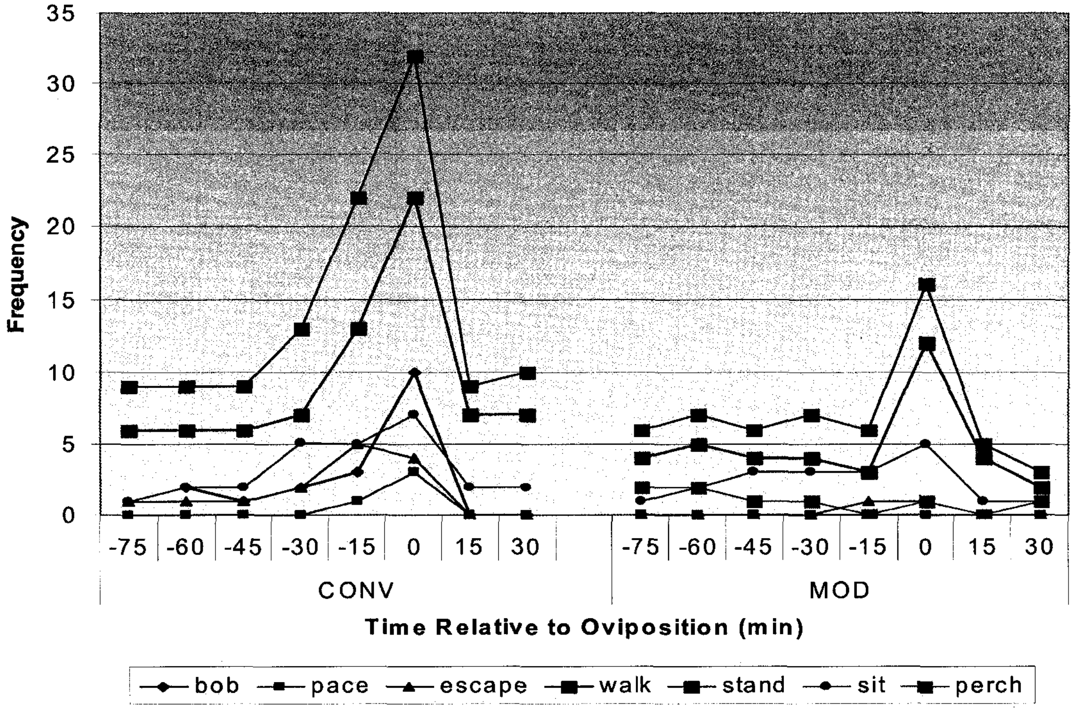


Figure 2.9 Frequency (mean ± SEM) of agonistic and stereotyped behaviour of CONV and MOD hens during the 3 h interval in which hens oviposited *(*P <0.05)*.

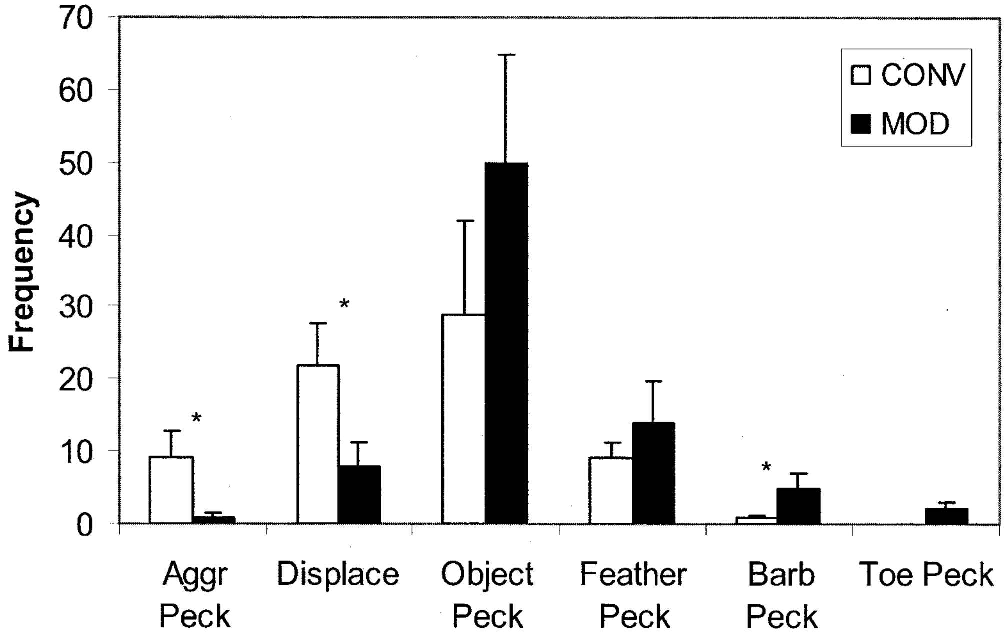


Figure 2.10 Frequency of agonistic and stereotyped behaviour of CONV and MOD hens during 15 min intervals beginning 90 min prior to oviposition and ending 30 min post oviposition.

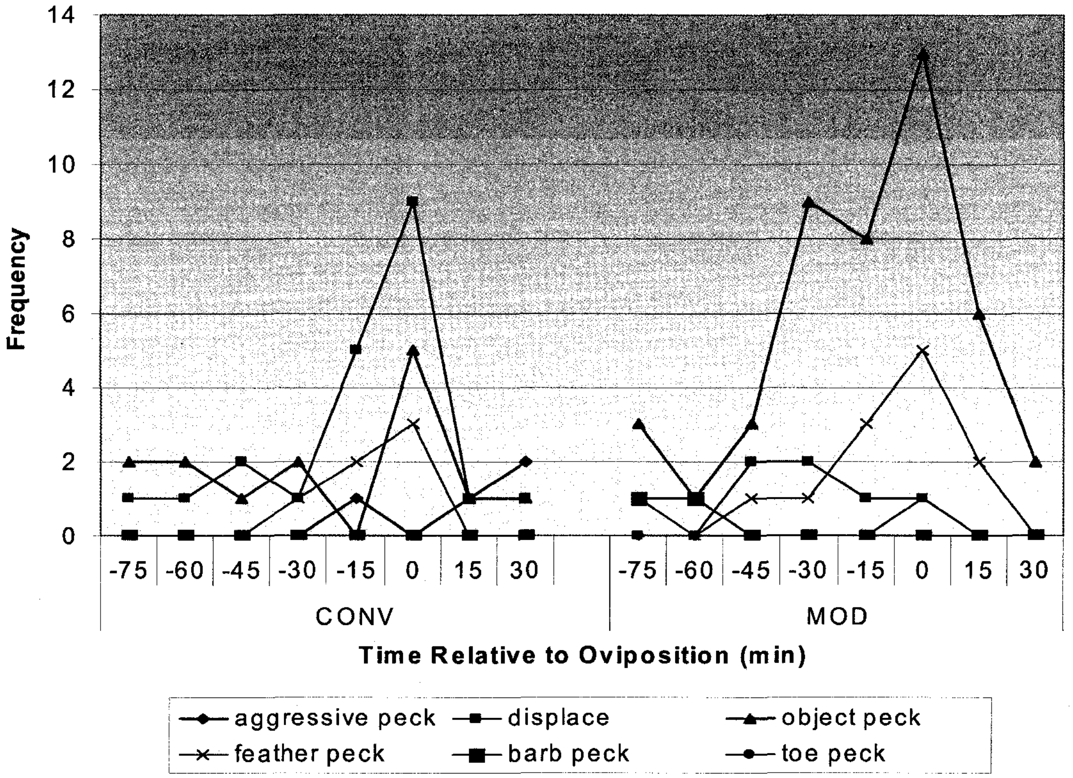


Figure 2.11 Frequency (mean ± SEM) of comfort behaviour of CONV and MOD hens during the 3 h interval in which hens oviposited *(*P <0.05)*.

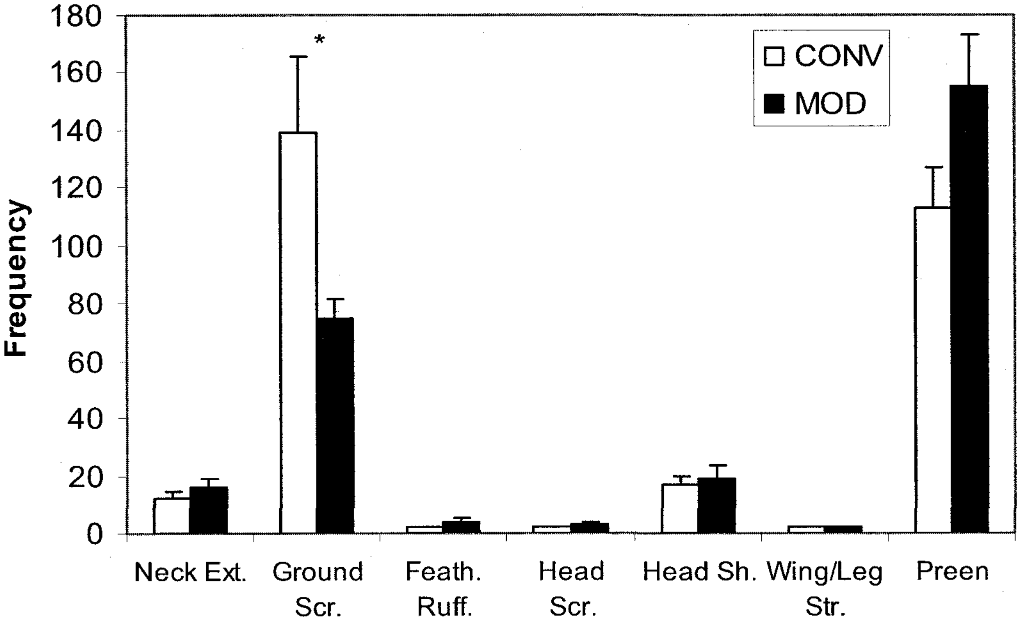


Figure 2.12 Percent duration (mean ± SEM) of comfort behaviour of CONV and MOD hens during the 3 h interval in which hens oviposited *(*P <0.05)*.

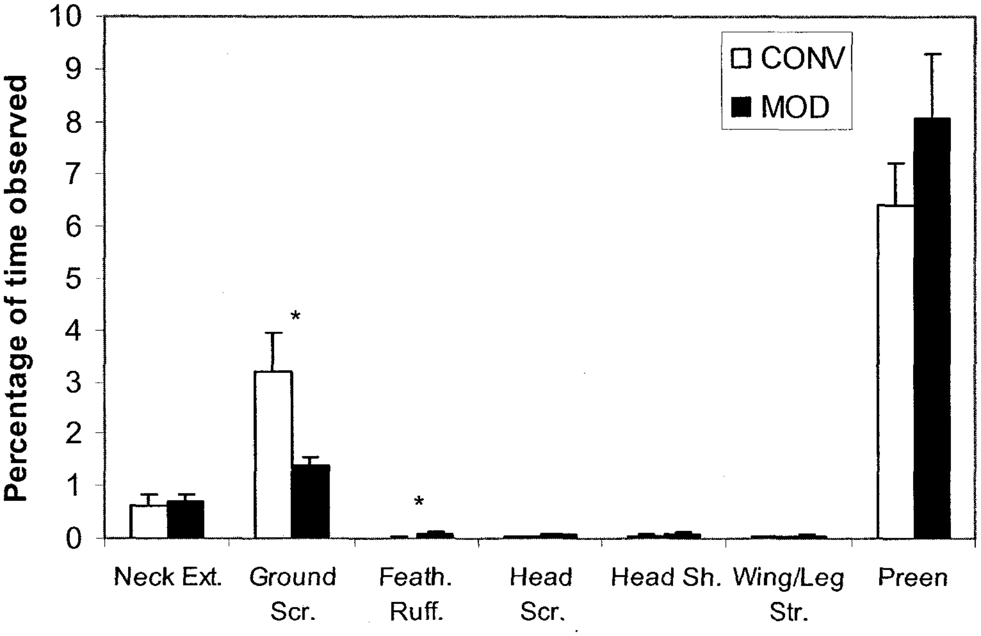


Figure 2.13 Frequency (mean ± SEM) of comfort preening of CONV and MOD hens during the 3 h interval in which hens oviposited *(**P <0.01)*.

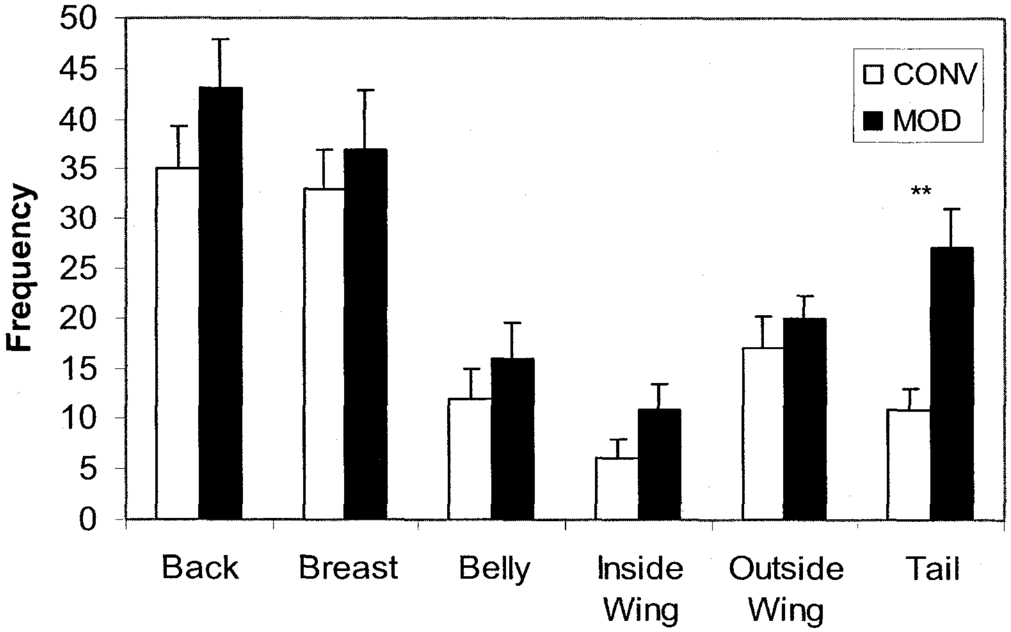


Figure 2.14 Percent duration (mean ± SEM) of comfort preening of CONV and MOD hens during the 3 h interval in which hens oviposited *(**P <0.01)*.

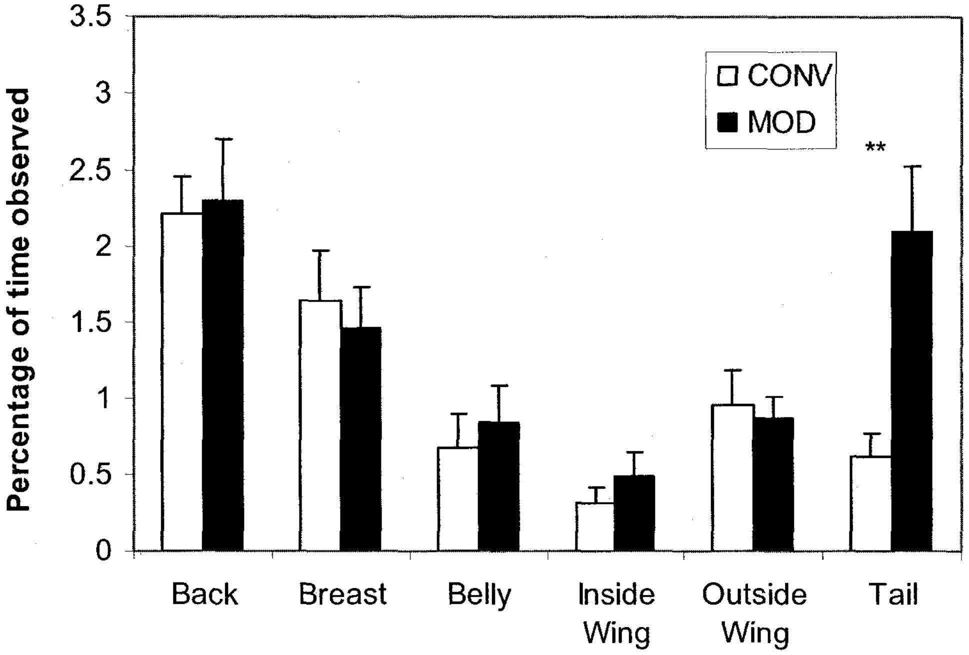


Figure 2.15 Frequency of comfort behaviour of CONV and MOD hens during 15 min intervals beginning 90 min prior to oviposition and ending 30 min post oviposition.

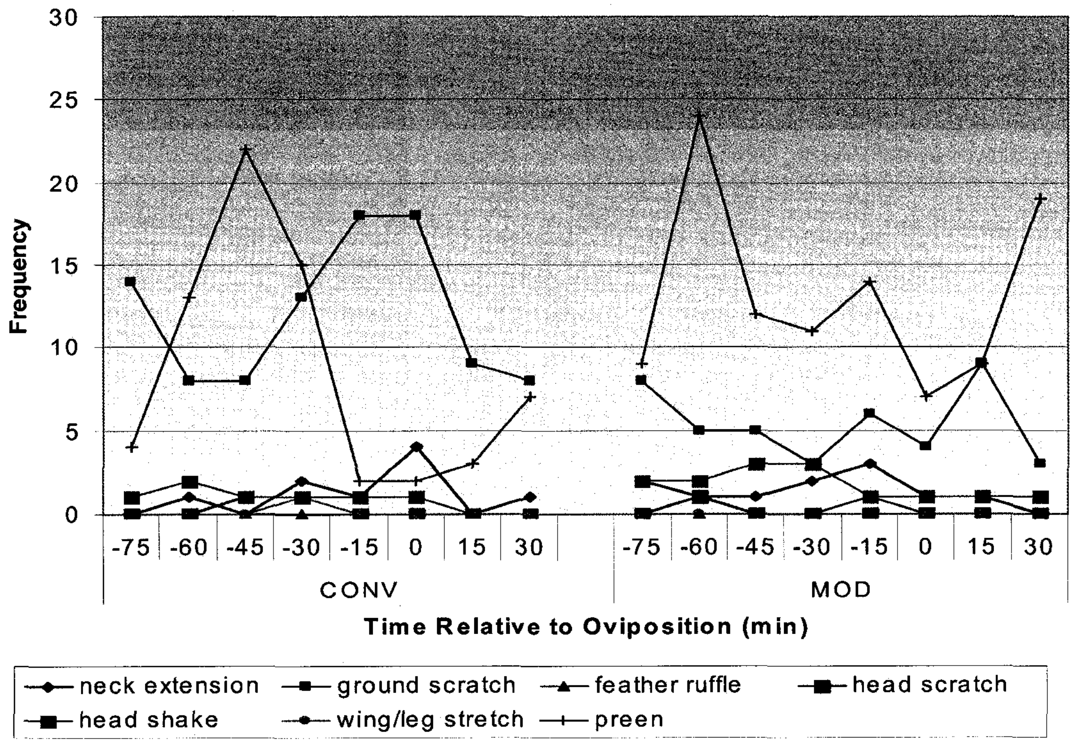


Figure 2.16 Frequency of comfort preening of CONV and MOD hens during 15 min intervals beginning 90 min prior to oviposition and ending 30 min post oviposition.

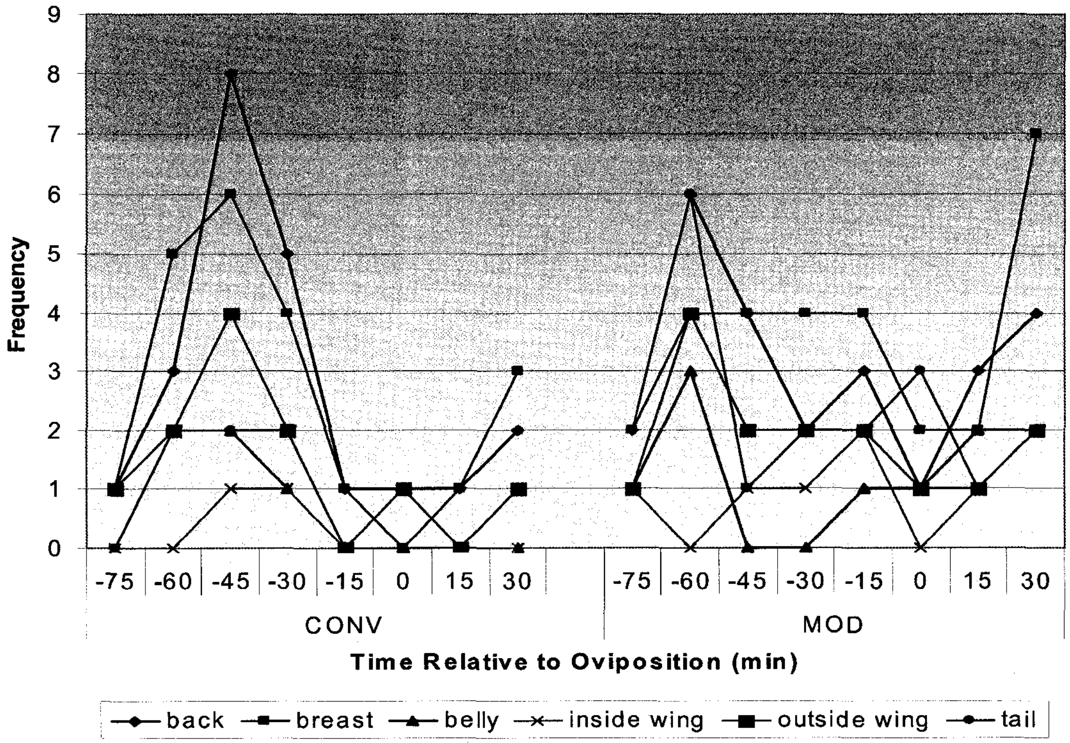


Figure 2.17 Percent duration (mean ± SEM) of rest and ingestive behaviour of CONV and MOD hens during the 3 h interval in which hens oviposited *(***P <0.001)*.

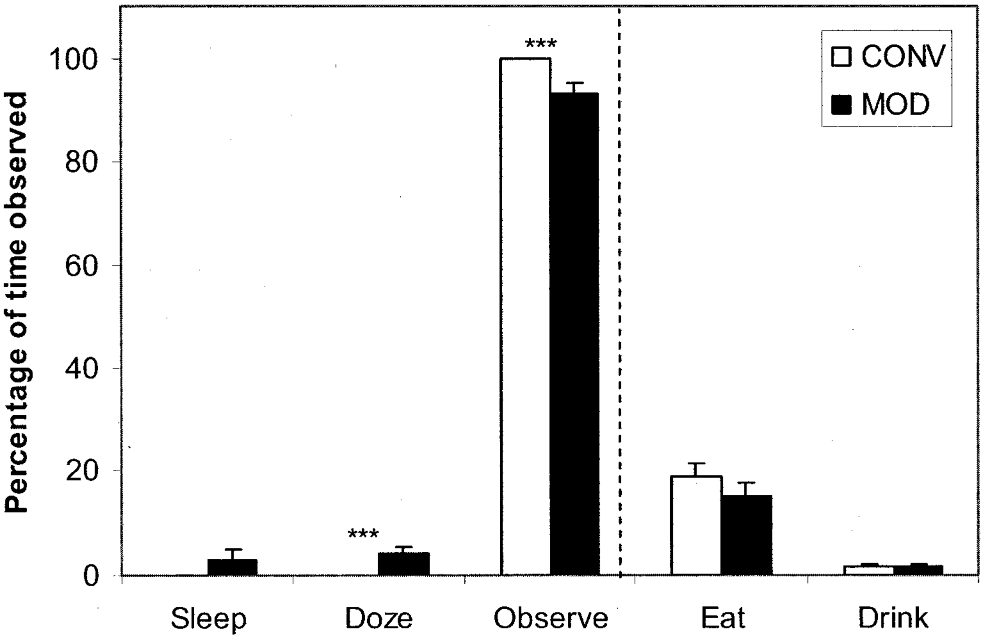


Figure 2.18 Frequency of rest and ingestive behaviour of CONV and MOD hens during 15 min intervals beginning 90 min prior to oviposition and ending 30 min post oviposition.

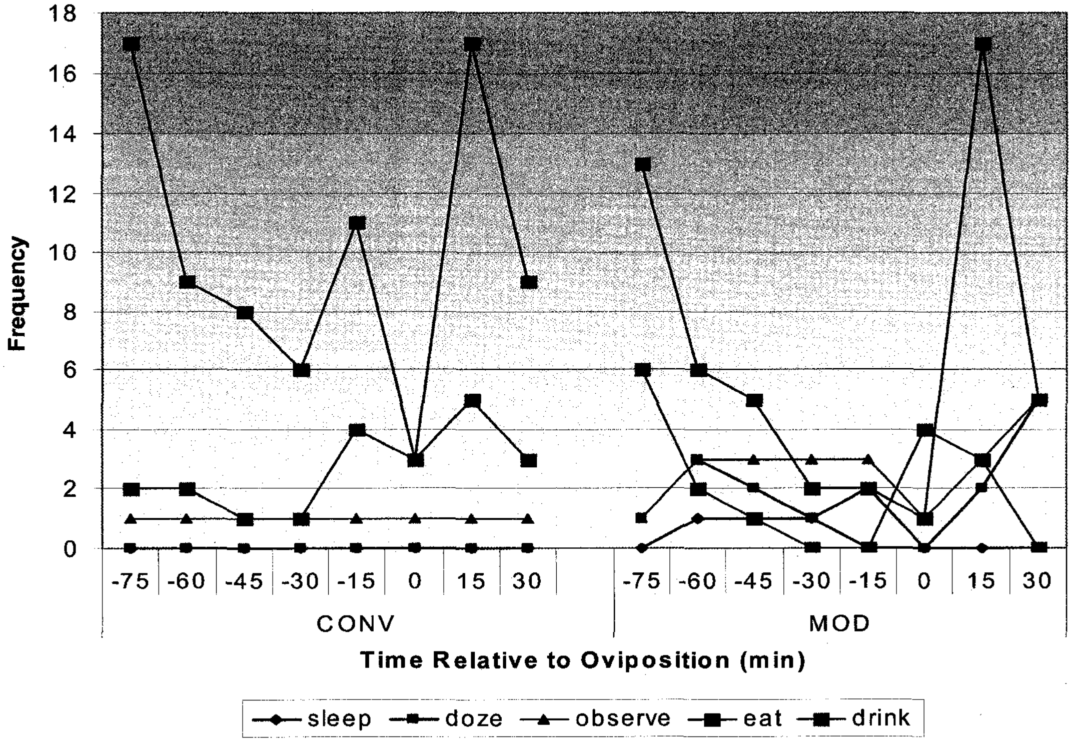


Figure 2.19 Percent duration (mean ± SEM) of time spent at each location by CONV and MOD hens during the 1 h interval between 06:30 and 07:30.

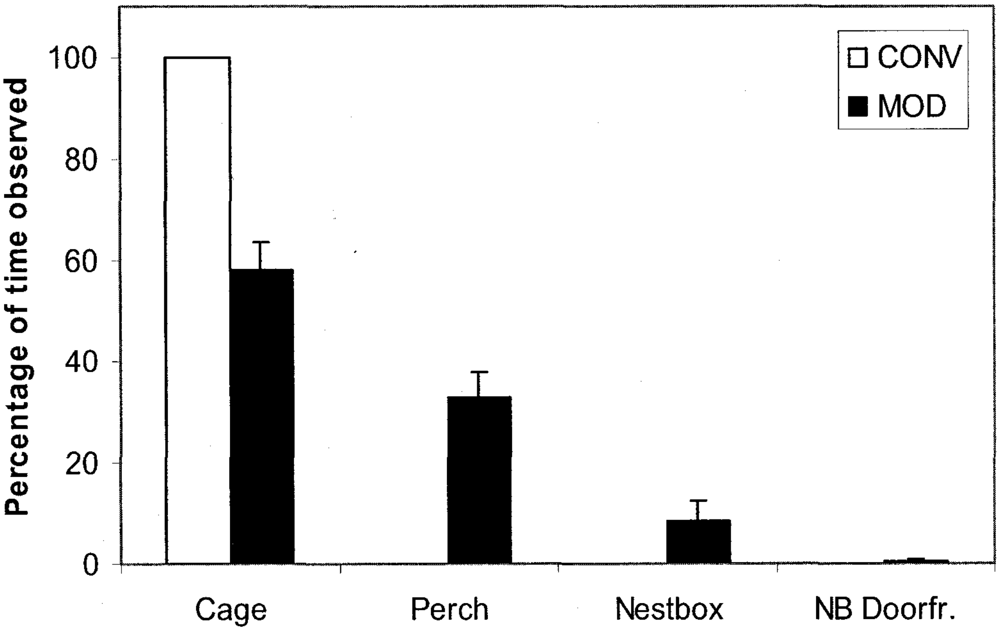
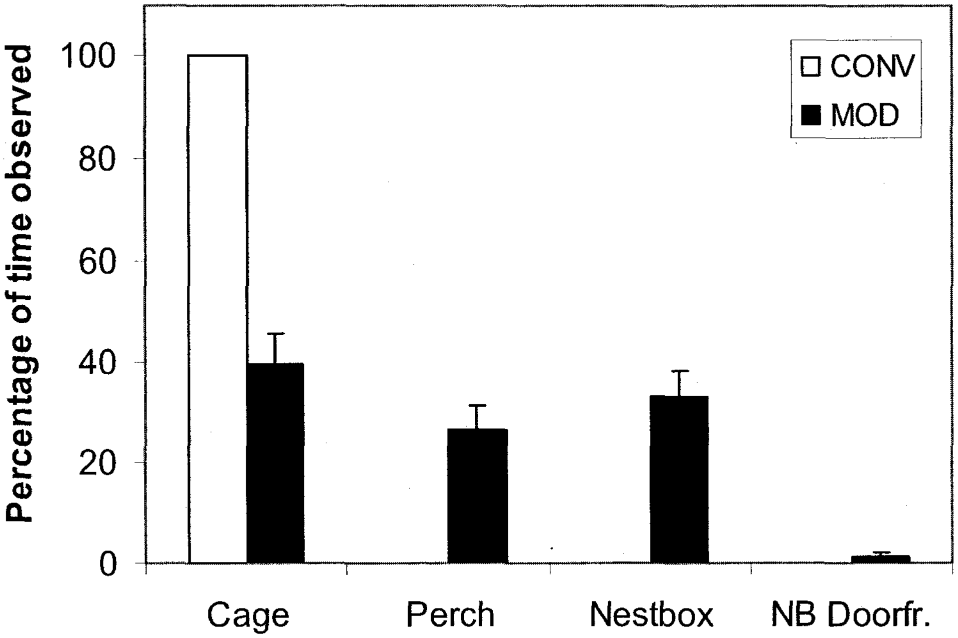


Figure 2.20 Percent duration (mean ± SEM) of time spent at each location by CONV and MOD hens during the 3 h interval in which hens oviposited.



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Chapter 3

Dustbathing behaviour in furnished colony cages: Implications for laying hen welfare

This chapter has been prepared in the format of the scientific journal Applied Animal Behaviour Science in preparation for future submission.

3.1 Abstract

The objective of this study was to assess the contribution of a substrate-filled dustbath to the welfare of laying hens housed in furnished cage systems by monitoring dustbathing behaviour. Floor litter raised White Leghorn hens were housed in furnished 26-hen colony cages containing an artificial turf-lined nest box and perch. Hens were provided with unrestricted access to the nest box and, in half of the cages (CWDB), had daily access to a peat-filled dustbath from 1300 to 1800 h. In the remaining cages (CWODB), the dust bath was kept closed and peat substrate was added along the narrow edge of the closed facility. Focal sampling of dustbathing behaviour was conducted to assess the number of hens who performed true and sham dustbathing, the frequency of true and sham dustbathing bouts, and the location of the sham bouts. Average latency to dustbathe post peat addition and average dustbath duration were recorded. CWDB hens performed sham bathing on the cage wire floor and on artificial turf in the nest box, despite the presence of a peat-filled dustbath, however the combined frequency of true and sham bathing in CWDB, as well as the total number of hens observed to perform true and sham bouts in CWDB was higher than respective sham values in CWODB, and reflects an overall increase in the expression of the behaviour in the presence of a dustbath. Similarities between the total number of sham baths, total number of hens who sham bathed on the cage wire floor and in the nest box, and the total number of sham bouts per hen in CWDB and CWODB may suggest that not all bathing in the socially competitive dustbath in CWDB was sufficient to fulfill the hens' behavioural needs. Shorter latency to perform true dustbathing than to sham bathe post substrate addition suggests that hens were more highly motivated to dustbathe in a litter-filled facility than to sham bathe on

wire, and that hens were intrinsically motivated to dustbathe, rather than alone by the daily addition of peat substrate. Preferences for feed over peat and artificial turf as substrate for hens who sham bathed provides additional evidence that peat substrate was not a primary stimulus for bathing behaviour by these birds. Longer average bout durations in the dustbath than sham bouts durations performed in CWDB or CWODB suggest that sham bouts were unsuitable. However, shorter than normal duration of true bouts in CWDB also suggests that competition for bathing space prevented hens from fully expressing dustbathing behaviour in the dustbaths provided. The findings from this study provide evidence that hens are highly motivated to perform dustbathing in loose litter, and when deprived of this opportunity or of an adequate bathing environment, will seek to express the behaviour in the proximity of a particulate substrate. Providing adequate dustbathing facilities where hens can fully express dustbathing behaviour is therefore essential to improve the welfare of caged hens.

3.2 Introduction

Dustbathing is a maintenance behaviour performed by Galliforme birds (Simmons, 1964). The behaviour appears to function in the removal of excess stale feather lipids (Borchelt and Duncan, 1974; van Liere, 1992), and may contribute to the improvement of feather structure (Healy and Thomas, 1973) and the removal of ectoparasites (Simmons, 1964). Adult fowl typically perform the behavior after every 2 days of feather lipid accumulation (Vestergaard, 1982; van Liere, 1992), and dustbathing is most commonly observed in the middle of the day (Vestergaard, 1982). The behaviour may also be triggered by external factors such as heat and light (Hogan and van Boxel, 1993), the sight of suitable dustbathing substrate (Petherick et al. 1995) or the sight and sound of other hens bathing (Duncan et al., 1998).

Dustbathing is believed to be a highly motivated behaviour since hens will work to gain access to litter substrate (Widowski and Duncan, 2000). Furthermore, when deprived of the opportunity to bathe in litter, hens exhibit signs of stress and frustration (Vestergaard et al. 1997) and will perform dustbathing behavioural elements in a sham form, such as on a cage wire floor (Appleby et al., 1993; Petherick et al., 1995). Dustbathing consists of series of complex, and time and energy consuming behavioural sequences (Larson et al., 2000), which suggests that performance of the behaviour is of considerable value to the bird (Vestergaard et al; 1997). Additionally, following a period of litter deprivation, hens will exhibit increased dustbathing activity (Vestergaard, 1982), suggesting that the behavioural need may only be satisfied by performance of the true form of the behaviour (Merrill and Nicol, 2005).

Despite indications that dustbathing is a highly motivated behavioural priority and that preventing hens from performing the behaviour reduces hen welfare, the vast majority of laying hens worldwide are housed in conventional battery cages where true dustbathing behaviour cannot be expressed. As of 2012, the European Union will prohibit the further use of conventional battery cages, and only cage systems that provide hens with access to a nest site, perches and litter for foraging, claw shortening devices and increased cage area and height will be further permitted (CEC, 1999). Many furnished cage designs also attempt to accommodate dustbathing behaviour either in the litter area or through provision of a distinct dustbathing facility. To avoid logistical and economic implications of providing loose litter in a cage system, more often cage designs attempt to satisfy both foraging and dustbathing behavioural needs by providing non-litter substrates such as Astroturf pads, and hens have been observed to prefer dustbathing on artificial turf (Hughes, 1993) or artificial turf sprinkled with sand (Appleby et al., 2002) to bathing on the cage wire floor.

To assess the contribution of a substrate-filled dustbathing facility to the welfare of laying hens housed in cage systems, this study compared dustbathing behaviour under conditions in which hens were provided with access to a dustbathing facility and loose and non-litter substrate, and under conditions in which hens could access loose and non-litter substrate, but not a true dustbathing facility.

3.3 Materials and Methods

This research was carried out in accordance with the Canadian Guide to the Care and Use of Experimental Animals (CCAC, 1993) and was authorized by the Faculty Animal Policy and Welfare Committee at the University of Alberta.

3.3.1 Animals and Management

White Leghorn layer chicks originating from Shaver parent breeder stock were obtained at one-day of age from a commercial supplier (Pacific Pride Chicks, Abbotsford, BC, Canada) were reared on floor litter in pens of 50 birds at the University of Alberta Poultry Research Centre, Edmonton, Alberta, Canada. Chicks were beak trimmed with a heated blade trimmer at one week of age and, at 19 weeks, birds were randomly allocated to one of two cage treatments housed within the same room. Between 20 and 24 weeks, day length was gradually increased from 10 h (0700 to 1700) to 14 h (0500 to 1900), and from 30 weeks until the end of the trial (65 weeks), one additional hour of light was introduced between midnight and 0100 h. Birds were hand fed a standard commercial layer diet in accordance with NRC requirements and primary breeder recommendations, and were provided with ad libitum access to feed and water throughout the trial. Feed was top dressed with 6 g oyster shell per bird per week from 32 weeks to the end of the trial. Manure belts were cleaned twice weekly.

3.3.2 Housing design

The cage housing system used in this study was a furnished colony battery (Parent Stock Cage System, Specht Canada, Stony Plain, AB, Canada) which consisted of 2 tiers of 12 cages, each measuring 120 cm wide, 110 cm deep and 51 cm high at the center. Each cage housed 26 hens and provided 450 cm^2 of floor space per bird. Cages also contained an artificial turf-lined metal nest box measuring 60 cm wide and 55 cm deep, providing an additional 126 cm^2 nest space per hen. Access to the artificial turf-lined NB was not restricted, and was gained through a single, 20 cm wide entranceway. The floor of the nest box was continuous with the floor of the cage.

On the side of the cage opposite to the nest box opening, a softwood perch extended the width of the cage (120 cm) and measured 5 cm deep and 2.5 cm high. A metal dust bath measuring 60 cm wide and 20 cm deep was present in all 24 cages. All colony units had solid metal sides.

3.3.3 Colony cage With Dust Bath (CWDB)

In 12 of the 24 furnished colony cages, the dustbath was opened daily at 1300 h, filled with peat substrate (Fig. 3.1), and closed one hour before lights were turned off. Since motivation to dustbathe is highest in the middle of the day (Vestergaard, 1982), access was limited to a 5 h period in the afternoon, to minimize egg laying in the dustbath.

3.3.4 Colony cage Without Dust Bath (CWODB)

In the remaining 12 furnished colony cages, the dustbath was not opened but birds could jump up to and perch on the edge of the closed amenity. During the first week of the trial, CWODB cages were opened at 1300 h and a handler simulated addition of substrate to the dust bath, similar to the manner in which peat was added to the dustbaths in CWDB. It soon became apparent however, that hens in CWDB were readily consuming the peat substrate, regardless of whether they subsequently bathed in the substrate or not. To ensure that experimental measures not addressed in the current study were not affected by differences in hen feeding behaviour, it was therefore decided to also incorporate a small amount of peat along the edge of the closed dustbaths in CWODB (Fig. 3.2). Since peat has been shown to be a strong external stimulus for triggering dustbathing behaviour (Petherick et al., 1995) the addition of peat to CWODB cages would also ensure that hens in both CWDB and CWODB were equally motivated by the presence of the same litter and non-litter substrates (peat and artificial turf).

3.3.5 Video recording and behavioural observations

At 34 weeks, one week prior to video recording, camera mounts and cables were installed in front of 8 randomly selected cages per treatment, to allow hens to acclimatize to the presence of the equipment. One mount was positioned facing the dustbath, a second mount was installed over the nest box and a third arm was installed to capture footage of the cage. Each night prior to filming, black and white closed-circuit video cameras equipped with a 4.0mm lens (Delta Vision, i400LX, Concord, ON, Canada) were positioned on the mounts of 2 cages per treatment, and cables were connected to a quad processor system (Delta Vision, DV-Q4CHRTBW, Concord, Ontario, Canada) and VCR (Panasonic 6720A, Mississauga, Ontario, Canada). Filming of the cages was completed over a 4 day period at week 35.

Hen dustbathing behaviour was evaluated by assessing all true dustbathing bouts that occurred in the dustbath, and all sham dustbathing bouts that occurred in the nest box and on the cage wire floor in the 1 h period following peat substrate addition for all 26 hens in 4 cages per treatment. This period was chosen since substrate was most abundant, and the effect of substrate addition on hen motivation to bathe could be evaluated. The number of hens who entered the dustbath was also recorded, regardless of whether hens subsequently bathed therein or not. Since individual hens could not be distinguished, each dustbathing bout was focally assessed to determine treatment differences in sham dustbathing behaviour and the characteristics of true dustbathing in CWDB, the number of hens who bathed and frequency of bathing bouts, latency (time delay) to begin bathe post peat addition, and average dustbathing durations for all true and sham bathing activity. Where multiple bouts performed by the same hen could be identified, average duration of the first bout and average duration of the longest bout were also noted. A dustbathing bout was recorded as having begun when a hen squatted and ended when a hen stood, and a bout was only considered complete if one or more of the following behavioural elements was observed: scratching, vertical wing shaking, head or side rubbing, vigorous body shake, wing or leg stretch, pecking and bill raking. Observations were recorded using the software of Observer 5.0 (Noldus Information Technology, The Netherlands, 2002). Locations where sham bouts were performed were also recorded.

3.3.6 Statistical analysis

All statistical analyses of behavioural data were conducted using procedures of SAS (SAS Institute, 2002). For the number of hens who bathed and frequency of bathing bouts, the cage was the experimental unit of measure, and the hens were the sample units. Means were calculated per cage, assessed for normality of distribution, and transformed by square root transformation where necessary. For latency and duration of bathing bouts, and number of bouts per hen, hens were both the sample and experimental unit. Means were calculated per treatment, assessed for normality of distribution, and transformed by log transformation where necessary. Treatment differences in dustbathing frequency, latency and duration were then assessed using the two-sample t-test. The level of significance for all statistical analyses was assessed at $P \leq 0.05$.

3.4 Results

3.4.1 Frequency of dustbathing bouts and number of hens who dustbathed

The number of hens observed to enter the dustbath, bathe in the dustbath, or sham bathe on the cage wire floor or in the nest box totaled 118 in CWDB and 35 in CWODB. True dustbathing activity performed in the dustbath was only observed by CWDB hens. Hens in CWODB did enter the dustbath to peck at peat or to gain access the adjacent nipple drinker but did not attempt to dustbathe on the narrow ledge of the closed dustbath.

As shown in Fig. 3.3 (a), the total number of hens who performed true or sham dustbathing bouts and the combined total number of true and sham dustbathing bouts, was higher in CWDB than in CWODB (P=0.02 and P=0.001, respectively). The number of hens observed to perform true bouts in CWDB (Fig. 3.3 (b)) did not differ from the number of hens observed to perform sham bouts in CWODB (21 ± 2) (P=0.09). However, the frequency of true bouts in litter in CWDB (Fig. 3.3 (b)) was higher than the combined frequency of sham bouts in the nest box and on the cage wire floor in CWODB (39 ± 4) (P=0.03). The number of hens who performed sham bouts in CWDB (39 ± 2) did not differ from the number of hens who performed sham bouts in CWODB (21 ± 1) (P=0.18), and the number of sham bouts performed in CWDB (77 ± 5) did not differ from the number of sham bouts performed in CWODB (39 ± 3) (P=0.19).

On the cage wire floor (Fig. 3.3 (c)), neither the number of hens who performed sham dustbathing nor the number of sham bouts on the wire floor differed between CWDB and CWODB (P=0.32 and P=0.40, respectively). Also, neither the number of hens who performed sham dustbathing in the nest box (Fig. 3.3 (d)), nor the number of sham bouts in the nest box differed between CWDB and CWODB (P= 0.99 and P=0.49, respectively).

Only 42% of CWDB hens observed to enter the dustbath subsequently performed dustbathing in the dustbath. The number of true bouts in CWDB (Fig. 3.3 (b)) did not differ significantly from the combined number of sham bouts in CWDB (77 ± 9) (P=0.20). Additionally, the number of hens who performed true bouts in CWDB (Fig. 3.3 (b)) did not differ from the number of hens who performed sham bouts in CWDB (39 ± 4) (P=0.72).

In CWDB, the total number of sham bouts was higher on the cage wire floor (69 ± 8) than in the nest box (8 ± 1) (P=0.05) and the total number of hens who sham bathed was higher on the cage wire floor (35 ± 3) than in the nest box (4 ± 1) (P=0.04). In CWODB, the total number of sham bouts was higher on the cage wire floor (36 ± 4) than in the nest box (3 ± 0) (P=0.05), and the total number of hens who sham bathed was higher on the cage wire floor (19 ± 2) than in the nest box (2 ± 0) (P=0.05).

As shown in Fig. 3.4, treatment differences in sham bathing bouts per hen were not apparent for bouts performed on the cage wire floor (P=0.46) or in the nest box (P=0.65). For location of bouts per hen, differences between the number of sham bouts occurring on cage wire floor and the number of bouts occurring in the nest box were neither observed in CWDB (P=0.21), nor in CWODB (P=0.22). In CWDB, bouts per hen in the dustbath were higher than bouts per hen in the nest box (P=0.01), bouts per hen in the dustbath did not differ from bouts per hen on the cage wire floor (P=0.08), and bouts per hen on the cage wire floor did not differ from bouts per hen in the nest box (P=0.21). In CWODB, bouts per hen on the cage wire floor did not differ from bouts per hen in the nest box (P=0.22) (Fig. 3.4).

3.4.2 Latency to Dustbathe

Latency of CWDB hens to perform true dustbathing (944 ± 184 s) was not shorter than latency for CWODB hens to perform sham bathing in the NB (1376 ± 418 s) (P=0.58) but was shorter than latency for CWODB hens to sham bathe in the cage (2312 ± 190 s) (P<0.0001). As shown in Fig. 3.5, latency to dustbathe post substrate addition did not differ between treatments for sham bouts performed on the cage wire floor (P=0.08) or in the nest box (P=0.19). The average latency to dustbathe in the dustbath of CWDB post peat addition was 944 (± 184) s and ranged from 14 to 3601 s. In CWDB, latency to dustbath post entry into dustbath was 69 (± 17) s and ranged from 3 to 463 s.

For CWDB hens, latency to dustbathe in the dustbath was shorter than latency to sham bathe on the cage wire floor (1770 ± 211 s; P=0.004) or on the artificial turf in the nest box (2602 ± 342 s; P=0.007) of CWDB. In CWDB, no difference between latency to sham bathe in the nest box (1376 ± 418 s) and on the cage wire floor (2312 ± 190 s) (P=0.13) was apparent. Latency to sham bathe did not differ between the nest box (2602 ± 342 s) and the cage (1770 ± 211 s) (P=0.17) for CWDB hens. In CWODB, no difference in latency to sham bathe post peat addition was observed between sham dustbathing in the nest box (1376 ± 418 s) and sham dustbathing on the cage wire floor (2312 ± 190 s) (P= 0.13).

3.4.3 Dustbathing Duration

As shown in Fig. 3.6(a), sham bouts in the nest box were significantly shorter for CWDB hens than CWODB hens (P=0.03) but no treatment differences in average bout duration were apparent for sham bathing occurring on the cage wire floor (P=0.76). For CWDB hens, the average duration of a true bout in the dustbath (377 ± 67 s) was significantly longer than the average duration of a sham bout in the nest box (64 ± 22 s) (P=0.02) or on the cage wire floor (191 ± 32 s) (P=0.003). Average durations of sham bouts occurring in the nest box did not differ from those occurring on the cage wire floor (P=0.33). For CWODB hens, the average duration of a sham bath occurring in the nest box (323 ± 53 s) did not differ from the average duration of a sham bath performed on the cage floor (109 ± 25 s) (P=0.70).

CWDB hens performed shorter first sham baths in the nest box than CWODB hens (P=0.03) but longer first sham baths on the cage floor than CWODB hens (P=0.04) (Fig. 3.6 (b)). For CWDB hens, the average duration of a first true bout in the dustbath (411 ± 98 s) was significantly longer than a sham bout in the nest box (62 ± 24 s) (P=0.05) or on the cage wire floor (195 ± 32 s) (P=0.01). Average durations of first sham bouts occurring in the nest box did not differ from those occurring on the cage wire floor (P=0.45). For CWODB hens, the average duration of a first sham bath occurring in the nest box (323 ± 53 s) did not differ from the average duration of a first sham bath performed on the cage floor (100 ± 26 s) (P=0.74).

As shown in Fig. 3.6 (c), on average, the longest true dustbath in CWDB lasted 687 (± 86) s. The average duration of the longest sham bath did not differ between CWDB and CWODB for bouts performed in the nest box (P=0.10), however the longest sham bouts performed on the cage wire floor were lengthier for CWDB hens than CWODB hens (P=0.04). For CWDB hens, the average duration of the longest true bout in the dustbath (687 ± 86 s) was significantly longer than a sham bout in the nest box (109 ± 39 s) (P=0.001) or on the cage wire floor (228 ± 35 s) (P<0.0001). Average durations of the longest sham bouts occurring in the nest box did not differ from those occurring on the cage wire floor (P=0.46). For CWODB hens, the average duration of the longest sham bath occurring in the nest box (323 ± 53 s) did not differ from the average duration of the longest sham bath performed on the cage wire floor (147 ± 37 s) (P=0.93).

3.5 Discussion

3.5.1 Frequency of dustbathing bouts and number of hens who dustbathed

The higher combined frequency of true and sham bathing in CWDB, as well as the higher total number of hens observed to perform true and sham bouts in CWDB reflects an overall increase in expression of dustbathing behaviour, as a result of providing caged hens with a dustbathing facility. It has been suggested that sham bathing may be sufficiently adequate to satisfy hen motivation to dustbathe (Lindberg and Nicol, 1997; Widowski and Duncan, 2000), however Van Liere (1992) argues that since Galliformes have specialized to bathe in dust, birds may be unable to adapt feather maintenance behaviour to a dustless environment. Only in CWDB cages in the present study then, would hens have had opportunity to adequately express dustbathing behaviour. Permitting caged birds to perform this maintenance behaviour and to control the condition of their integument by provision of a dustbath therefore likely improved hen welfare.

Although the presence of a substrate-filled dustbath in CWDB encouraged the performance of true dustbathing activity, it did not prevent the performance of sham bathing on the cage wire floor or on the artificial turf in the nest box. This finding is consistent with previous studies examining dust bathing behaviour in cage systems (Lindberg and Nicol, 1997; Olsson and Keeling, 2002). Since hens within the same cage could not be distinguished from one another by the observer, it is also possible that the higher combined frequency and number of hens performing true and sham bathing activity in CWDB occurred because birds who bathed in the dustbath had previously, or then subsequently, bathed on the cage wire floor or in the nest box. In this case, repetition of the motor pattern would suggest that the behavioural expression was functionally incomplete regardless of location where the dustbath was performed, causing hens to seek another location in which to fulfill their motivation to dustbathe. This intimation is supported by the finding that in some cages, the total number of hens observed to perform bathing exceeded the actual number of hens in the cage. Also, given that under unrestricted conditions hens typically only bathe every second day (Vestergaard, 1982), the number of hens observed to bathe in the cage would therefore be expected to be less than the actual number of hens in the cage.

Similarities between the total number of sham baths and total number of hens who sham bathed on the cage wire floor and in the nest box of CWDB and CWODB may also suggest that not all bathing in the dustbath in CWDB was sufficient to fulfill the hens' behavioural needs. Had all CWDB hens been able to satisfactorily perform true dustbathing in the dustbath, it would be expected that fewer hens would have performed sham bouts in CWDB. Comparable sham displays between the treatments may therefore indicate that hens were either unsatisfied by bathing in the dustbath, or were unable to gain access the dustbath. Notably, in the hour period observed post substrate addition, the dustbath was consistently occupied by no less than 3 hens, only 42% of hens observed to enter the dustbath subsequently bathed therein, and displacement of other birds who were bathing or attempting to bathe in the dustbath was frequent. In contrast, Olson and Keeling (2002) found that in furnished cages housing 7 hens, very little sham dustbathing occurred when the dustbath was occupied. The authors suggested that the absence of sham bathing when the dustbath was in use provided evidence that sham bathing was not the result of social competition for limited dustbath space in that trial. In the present study however, where 26 hens were potentially competing for a dustbath in which only 3 to 4 hens could simultaneously bathe, social competition likely contributed to the incidence of sham bathing. In large group cage housing arrangements, provision of adequate litter facilities to accommodate simultaneous bathing is therefore essential to benefit hen welfare.

Sham bathing bouts in cage systems lacking a loose substrate are often of short duration and fragmented since hens are likely to be interrupted when attempting to bathe on the cage floor (Appleby et al., 1993; Lindberg and Nicol, 1997). In the present study, similar numbers of sham bouts per hen between the two treatment conditions, and similar numbers of bouts per hen between true and sham bouts performed in CWDB, may further reflect the inability of CWDB hens to satiate their dustbathing motivation in the dustbath. Disruptions to true bouts occurring in the dustbath may either have led to repetitive attempts to bathe in litter, or may have caused hens to abandon the dustbath and attempt to satiate their dustbathing motivation on the cage wire floor or in the nest box.

The lack of attempts by CWODB hens to dustbathe on the narrow ledge of the closed dustbath indicates that CWODB hens were not externally motivated to bathe by the presence of the facility itself, even though the closed dustbath was lined with peat moss, a preferred dustbathing substrate (Petherick and Duncan, 1989). Furthermore, had CWODB hens been primarily stimulated to sham bathe by the daily addition of peat, the number of hens who sham bathed and the frequency of sham baths in CWODB may have been comparable to total bathing hen numbers and frequencies in CWDB, respectively. The higher total number of hens who performed true or sham dustbathing bouts and the higher combined total number of true and sham dustbathing bouts in CWDB than in CWODB therefore also provides evidence that CWODB hens were intrinsically motivated to dustbathe, rather than solely by the addition of substrate. Permitting hens to satiate this motivation by provision of an adequate dust bathing facility may therefore be necessary to ensure hen welfare needs are met.

Somewhat surprisingly, in both CWDB and CWODB, sham dustbathing was more prevalent on the cage wire floor than on the artificial turf in the nest box. Previous studies have demonstrated that hens prefer artificial turf over wire flooring as a substrate for sham bathing (Hughes, 1993; Appleby et al., 2002, Merrill et al., 2006). It is possible that the addition of peat substrate to the dustbaths in CWDB and CWODB attracted hens to the cage area to sham bathe in the proximity of a substrate, rather than on the artificial turf in the nest box. Indeed, dustbathing motor patterns in Galliformes are ordered to maximize contact between substrate particles and the proximal integument, and thereby facilitate removal of excess or stale feather lipids (van Liere, 1992). Olson and Keeling (2002) found that the majority of sham bathing activity performed in cage systems occurred at the dust bath or feed trough, where birds could presumably access a dusty substrate. In the present study, only 10% of all sham bouts were performed directly under the dustbath, 83% took place at the feeder and 7% occurred on the cage floor away from the feeder. In CWODB, none of the sham bouts were performed under the dustbath, 70% took place at the feeder and 30% took place on the cage floor away from the feeder. These findings provide additional evidence that the peat substrate was not a primary stimulus for dustbathing behaviour, and indicate that hens who sham bathed in CWDB and CWODB may have preferred feed over peat as a particulate substrate.

The minimal use of the artificial turf as a sham bathing substrate may also reflect the hens' preference to perform true and sham bathing activity in a less enclosed and private location than the nest box. Since it has been suggested that dustbathing is a socially facilitated behaviour (Wood-Gush, 1989), and that the sight and sound of hens bathing may stimulate the behaviour in conspecifics (Duncan et al., 1998), hens may not have been motivated to bathe in the secluded nesting area. Notably, hens who entered the nest box and did not sham bathe primarily used the space as a resting and preening area, or as a place to escape from aggressive cagemates. These findings further reflect the importance of dustbath design in accommodating dustbathing behaviour, particularly in large group cage environments.

3.5.2 Latency to Dustbathe

The observation that CWDB hens exhibited shorter latency to begin true bathing post substrate addition than CWDB or CWODB hens exhibited to begin sham bathing on the cage wire floor, provides additional evidence that hens were more highly motivated to dustbathe in litter than to sham bathe on wire, and that CWODB hens were intrinsically motivated to dustbathe, rather than alone by the daily addition of peat substrate. Provision of suitable litter facility in which hens can express dustbathing behaviour is therefore important to hen welfare.

The absence of differences in latency to sham bathe between treatments suggests that sham bathing in CWDB and CWODB was similarly motivated. Since previous studies have shown that latency to dustbathe decreases when hens who have been deprived of litter are then provided with litter access (Vestergaard, 1982; Colson et al., 2007), it might be expected that hens in CWDB, who had daily access to litter, would therefore have exhibited increased latency to true and sham bathe. Similar latencies between treatments, and similar latencies for true and sham bathing in CWDB therefore provides additional evidence that bathing activity in the dustbath in CWDB did not adequately fulfill hens' bathing motivation.

3.5.3 Dustbathing Duration

Significantly shorter average and first sham bout durations in the nest box for CWDB hens than for CWODB hens, and lengthier first and longest bout durations on the cage floor for CWDB hens than CWODB hens may suggest that birds who sham bathed in CWDB performed the behaviour for longer durations when in the proximity of particulate substrate, such as peat and feed, as a result of their experience bathing in peat. CWODB hens, who had never experienced the benefit of true bathing in litter substrate performed the behaviour for longer durations on artificial turf, rather than seeking out a comparable bathing environment to the dustbath. In contrast to Merrill et al. (2006) then, who suggest that provision of artificial turf inside the cage may provide a suitable substrate for dustbathing that improves the welfare of laying hens, the findings from the present study would suggest that hens have not adapted to a dustless environment (van Liere, 1992) and do require a litter substrate to satiate feather maintenance behaviour. Therefore, although hens may prefer artificial turf to cage wire floor in the absence of a loose-litter filled dustbathing facility, the provision of artificial turf does not necessarily satisfy the hens' behavioural need. Improving hen welfare may therefore require provision of a loose-litter substrate and an adequate bathing facility.

Notably, average true dust bout durations, first true dust bout durations and longest bout durations were lengthier in CWDB than average, first and longest bath average sham bout durations performed in the nest box or on cage wire floor. Previous studies which have also determined that dustbathing bouts on wire flooring are significantly shorter than bouts performed in a dustbath, have attributed duration differences to the unsuitableness of wire floor as a substrate, causing hens to interrupt and thereby shorten the length of the behaviour sequence (Appleby et al., 1993; Lindberg and Nicol, 1997).

Under unrestricted conditions, the average dustbathing bout of an adult bird lasts for approximately 20 to 27 minutes (Vestergaard, 1982; van Liere, 1992). In the present study, the average duration of the longest true dustbath in CWDB was approximately 11 minutes. This finding likely reflects disruptions to true bathing behaviour that occurred in CWDB and provides additional evidence that normal bathing behaviour was not possible in the dustbaths provided.

The findings from this study provide additional evidence that hens are highly motivated to perform dustbathing in loose litter, and when deprived of this opportunity or of an adequate bathing environment, hens seek to perform sham bathing in the proximity of a particulate substrate. In the large group cage housing systems examined in this study, social competition for dustbathing space lead to disruption of dustbathing bouts, hen displacement from the dustbath or reduced opportunity to enter the dustbath, causing hens to reattempt true bathing in the dustbath or to sham bathe on the cage wire floor. To fully satisfy the dustbathing motivation in caged laying hens, and thereby improve hen welfare, dustbath designs that adequately accommodate multiple hen use are required. In addition, in large group furnished cages, further studies in which individual hen behaviour can be monitored are necessary to better understand individual hen motivation and overall hen bathing satisfaction in a socially complex and competitive setting.

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3.7 Figures

Figure 3.1 True Dustbathing in CWDB

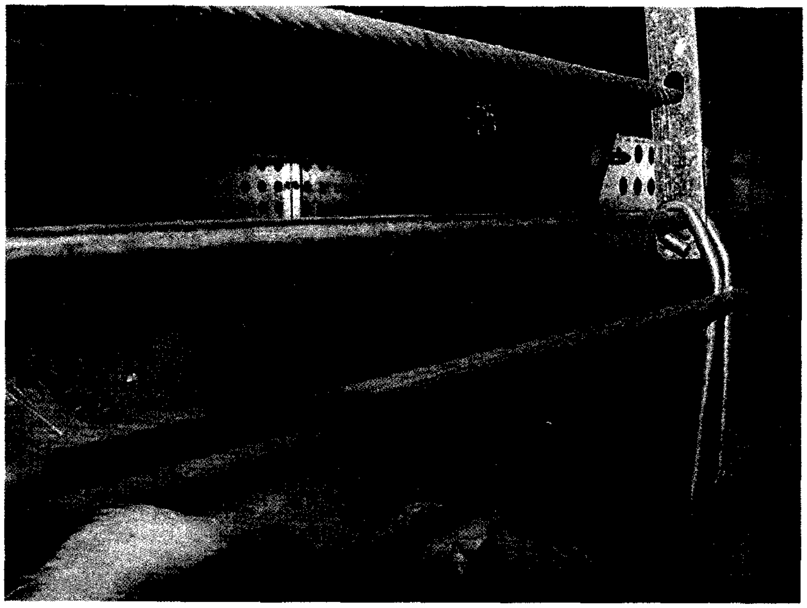


Figure 3.2 The Closed Dustbath in CWODB - Lined with Peat

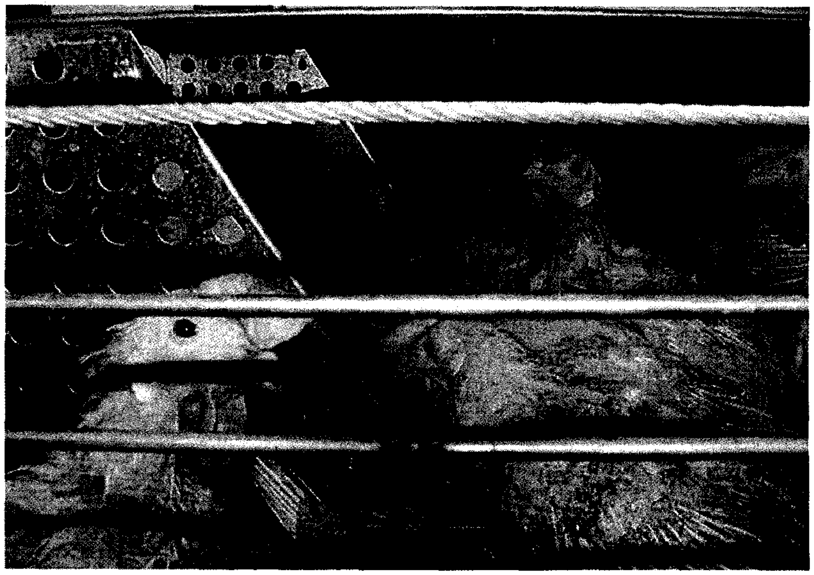
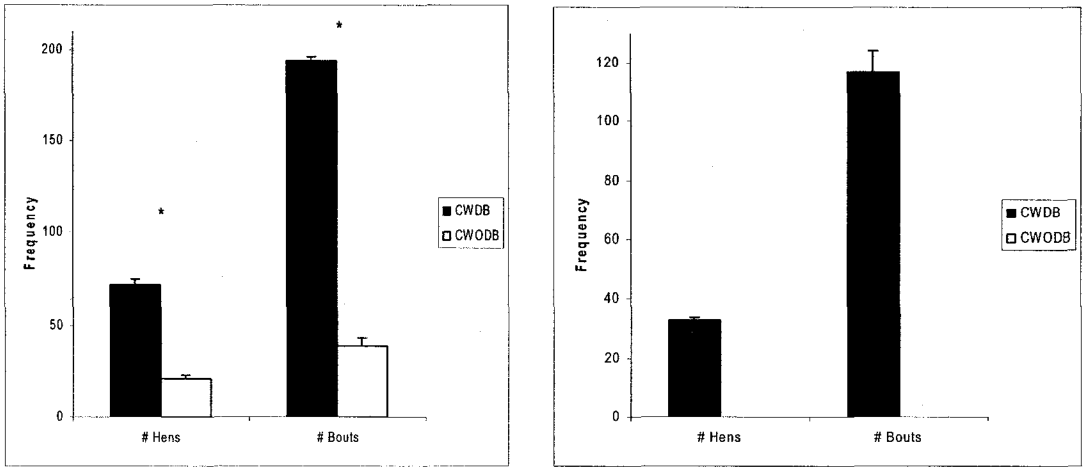


Figure 3.3 Mean (± SEM) dustbathing frequency *(*P <0.05).*

(a) Total Frequency (True and Sham) (b) Frequency in the Dustbath (True)



(c) Frequency On Cage Wire floor (Sham) (d) Frequency In the Nest box (Sham)

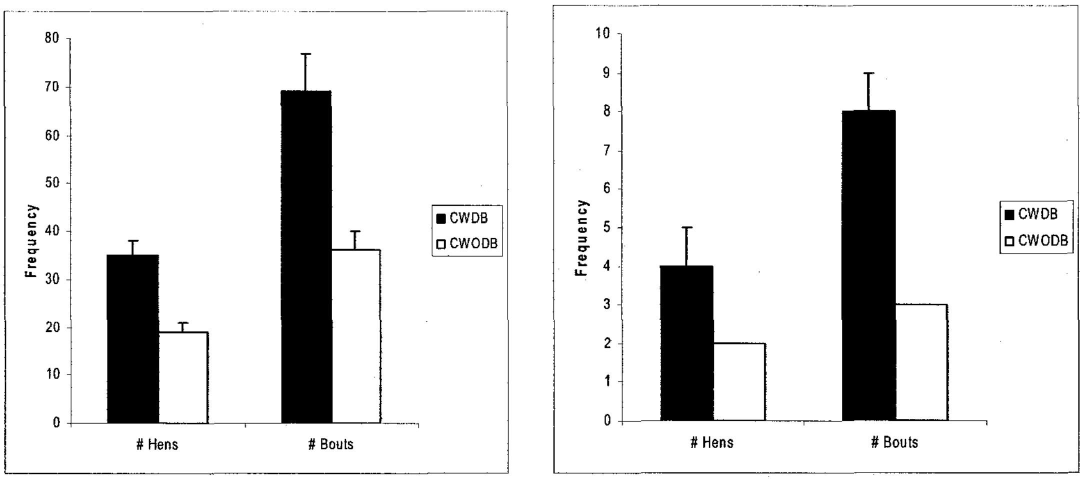


Figure 3.4 Mean (± SEM) dustbathing bouts per hen in the dustbath (true), on the cage wire floor (sham) or in the nest box (sham).

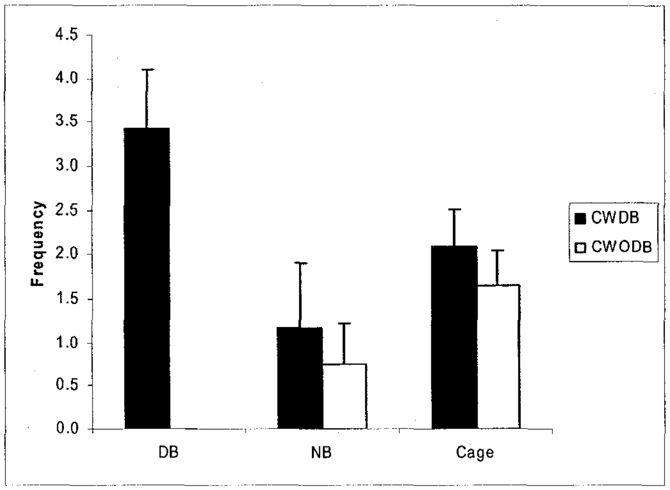


Figure 3.5 Mean (± SEM) latency to dustbathe (true or sham) post substrate addition (s).

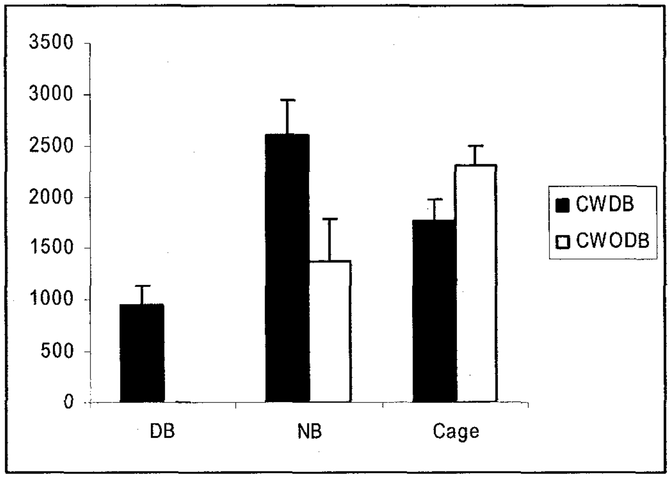
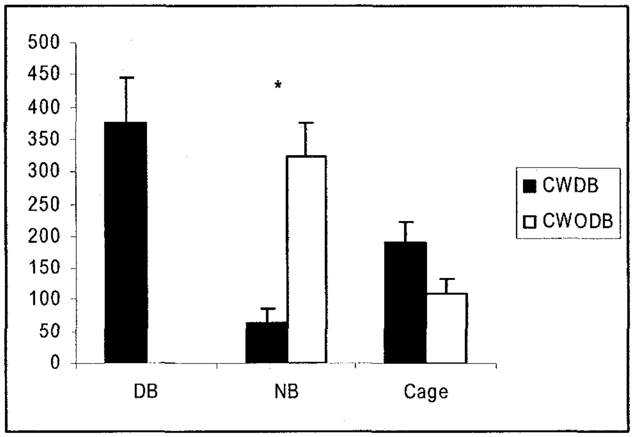
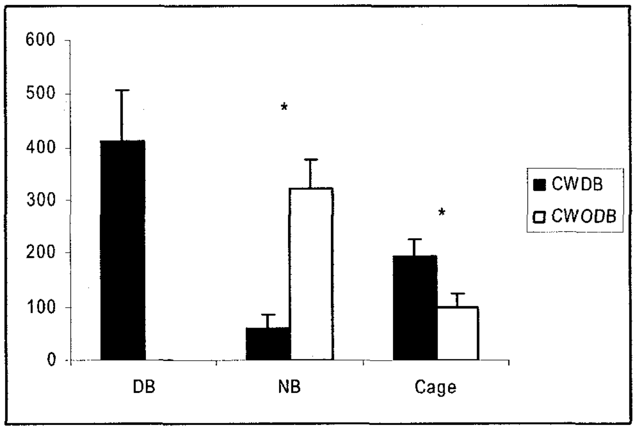


Figure 3.6 Mean (± SEM) duration of dustbathing (true or sham) *(*P <0.05).*

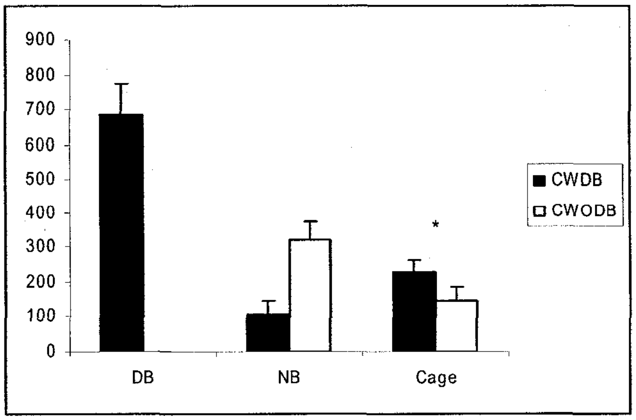
(a) Average Dustbath Duration (s)



(b) Average Duration of First Dustbath (s)



(c) Average Duration of Longest Dustbath (s)



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Chapter 4

Bone Mineral Density and Breaking Strength of White Leghorns Housed in Conventional, Modified and Commercially-Available Colony Battery Cages

A version of this chapter has been published.
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4.1 Abstract

Limited opportunity for movement and load-bearing exercise for conventionally-caged laying hens leads to bone loss, and increased susceptibility to osteoporosis, bone fractures and cage layer fatigue, all of which compromise hen welfare and have negative consequences for production. The objective of this study was to compare bone mineral density (BMD) and strength measures of White Leghorns housed in conventional battery cages (CONV), cages modified to incorporate a nest box and perch (MOD), and commercially-available, furnished colony cages with (CWDB) or without (CWODB) a raised dust bath. Hens reared on floor litter were randomly allocated to one of four cage systems at 19 wks of age. Hen-day production and egg quality were measured between 20 and 64 wks. At 65 wks, hens were euthanized and right femur, tibia and humerus were excised. BMD was assessed using quantitative computed tomography, and breaking strength was measured with an Instron Materials Tester. In the femur and tibia, CONV hens exhibited lower total BMD, bone mass, cortical bone area, cortical bone mass and bone breaking strength than CWDB, CWODB and MOD hens. Density and cross sectional area of bone in the trabecular space was highest in CONV. In the humerus, total and cortical BMD and mass, and breaking strength values were higher for colony-housed birds than hens in CONV and MOD. MOD birds did not exhibit increased humeral BMD or strength measures over CONV hens. These findings provide evidence that hens housed in modified and colony cages, furnished systems that promote load-bearing movement, are better able to preserve cortical structural bone than conventionally-caged hens, and simultaneously have stronger bones. Furthermore, inclusion of raised amenities that encourage wing loading is necessary to reduce humeral cortical bone loss. The overall

absence of correlation between egg production or quality, and bone quality measures also suggests that improved bone quality in CWDB, CWODB and MOD furnished cages is not the result of lowered egg production or quality.

4.2 Introduction

It is evident from the high incidence of broken bones observed among hens throughout the production period, and during depopulation, transport and shackling (Randall and Duff, 1988; Gregory and Wilkins, 1989; Budgell and Silversides, 2004), that osteoporosis has become a widespread condition in laying flocks. Osteoporosis, which is characterized by a progressive loss of fully mineralized structural bone throughout the skeleton, results in bone fragility, thereby increasing susceptibility to fracture (Whitehead and Fleming, 2000; Whitehead, 2004). In the extreme manifestation of structural bone loss, hens may succumb to cage layer fatigue, a condition characterized by spontaneous bone fracture, and vertebral weakening causing exposure of the spinal column and potential paralysis (Urist and Deutsch, 1960; Bell and Siller, 1962; Riddell et al., 1968). Acute and chronic pain, debilitation and mortality resulting from osteoporotic fractures pose serious animal welfare concerns (Webster, 2004) and incur economic loss during the production period and at processing.

Osteoporosis may result, in part, from prolonged periods of high egg production during which structural bone is mobilized without opportunity for regeneration (Whitehead and Wilson, 1992; Knowles and Wilkins, 1998). At the onset of sexual maturity, cortical and trabecular structural bone formation is ceased in favour of woven, medullary bone deposition (Wilson et al. 1992; Hudson et al., 1993; Whitehead and Fleming, 2000). However, during the period of eggshell construction, mobilization of medullary bone to increase calcium availability (Whitehead and Fleming, 2000; Whitehead, 2004) also results in resorption of exposed structural bone (Dacke et al., 1993). Consequently, over the course of the production cycle, the net effect of cortical and trabecular bone resorption without subsequent reconstruction is structural bone loss and skeletal weakening.

As demonstrated in studies comparing bone quality and breaking strength measures of conventionally-caged hens with those of birds housed in floor litter, perchery or aviary systems (Rowland et al., 1968; Rowland and Harms, 1970; Knowles and Broom, 1990; Nørgaard-Nielsen, 1990; Fleming et al., 1994; Abrahamsson and Tauson, 1995; Newman and Leeson, 1998), osteoporosis is also influenced by the extent to which movement and exercise are permitted in a housing system. Flight, wing flapping, walking, and perching, all of which involve load bearing, appear to contribute to the improved bone condition observed in non-cage systems (Knowles and Broom, 1990; Abrahamsson and Tauson, 1995). For caged hens, bone loss related to disuse may be minimized by providing birds with increased opportunity for movement, such as exposure to daily periods of exercise (Meyer and Sunde, 1974) or access to perches within the cage (Wilson and Hughes, 1993; Hughes and Wilson., 1993; Hughes and Appleby, 1989; Duncan et al., 1992).

As a result of the behavioural restrictions and limited opportunity for movement in conventional battery cages, many European countries have adopted legislative policies that regulate or prohibit the use of cage systems (SAWO, 1981; SFS, 1998; CEC, 1999; Tauson, 2003; BMEVL, 2007). In North America, laying hen husbandry practices are not regulated by legislation, and conventional battery cages remain the predominant housing system. Egg producers are encouraged to adopt minimum space allowances for caged hens (CARC, 2003; UEP, 2006), however, it remains questionable whether the provision of additional floor space is adequate to promote the activity and behavioural repertoires required to maintain structural bone (Lanyon, 1996).

A study was conducted to develop a modified laying hen cage system that would promote activity and behavioural repertoires conducive to bone, and overall hen health and welfare. The modified system, developed from conventional battery cages altered to incorporate a nest box and perch, would potentially provide North American producers with a practical option for promoting hen welfare using existing cage capital. The objective of this paper was to compare bone mineral density and strength measures of laying hens housed in conventional cages, the modified system and commercially-available furnished colony cages, to determine if bone health and therefore hen welfare, could be improved in cage systems.

4.4 Materials and Methods

4.3.1 Experimental Design

This research was authorized by the Faculty Animal Policy and Welfare Committee at the University of Alberta, and was conducted in accordance with the Guide to the Care and Use of Experimental Animals (CCAC, 1993). White Leghorn (Pacific Pride Chicks, Abbotsford, BC, Canada) layer chicks originating from Shaver parent breeder stock were raised in floor pens at a stocking density of 50 birds per pen. Chicks were beak-trimmed with a heated blade trimmer at one wk of age. At 19 wks, birds were randomly allocated to one of four cage treatments housed within the same room. Hens were hand fed a standard commercial layer diet in accordance with NRC requirements and primary breeder recommendations, and were provided with ad libitum access to food and water throughout the trial. Day length was gradually increased from 10 hrs (0700 to 1700) to 14 hrs (0500 to 1900), between 20 and 24 wks. One additional hour of light between midnight and 0100 h was introduced at 30 wks and continued until the end of the trial. Beginning at 32 wks, feed was top dressed twice weekly with 3 g oystershell per bird. At 39 weeks, this was altered to feeding 6 g oystershell per bird, once per week.

4.3.2 Cage Design

4.3.2.1 Conventional (CONV)

The conventional treatment consisted of 3 tiers of 14, 6-hen layer cages measuring 60 cm wide, 45 cm deep and 40 cm high at the rear. Cages in each tier were divided by installation of a vertical bar partition to give 28, 3-hen units per tier. A total of 252 hens were housed in the 84 cages, each hen having access to 450 cm^2 of floor space (Figure 4.1).

4.3.2.2 Furnished Cages - Modified (MOD)

Three tiers of 28, standard 6-hen layer cages were modified by addition of a wooden nest box and a softwood perch. Nest boxes were placed on the same side of each MOD cage, thereby creating solid cage sides between neighboring units. The nest box measured 24 cm wide, 45 cm deep and 35 cm high at the rear and was lined with artificial turf. Access to the NB could be achieved through one of two entrances located at the front and rear of the cage, each measuring 12 cm wide and 15 cm high, and raised 5 cm from the floor. A lightweight door was installed inside each NB and was opened and closed daily 30 min before lights were turned on and off, respectively. The perch, which extended from the nest box to the opposite wall of the cage was 30 cm long, 2.5 cm high and 5 cm deep, and was positioned 12.5 cm from the back of the cage and 32.5 cm from the front of the cage, at a height of 10 cm above the floor. Each of the 84 modified cages housed 3 hens, giving each of the 252 hens permanent access to 450 cm^2 of floor space, as well as 360 cm^2 of nest space during the day (Figure 4.1).

4.3.2.3 Furnished Cages - Colony cage With Dust Bath (CWDB), Colony cage Without Dust Bath (CWODB)

The furnished colony battery (Parent Stock Cage System, Specht Canada, Stony Plain, AB, Canada) consisted of 2 tiers of 12 cages, each measuring 120 cm wide, 110 cm deep and 51 cm high at the center. Each unit housed 26 birds and provided 450 cm^2 of floor space per hen. Metal nest boxes integrated as a continuum of the cage measured 60 cm wide and 55 cm deep, providing an additional 126 cm^2 per bird. Access to the artificial turf-lined NB was not restricted, and was gained through a single, 20 cm wide entranceway. Softwood perches extended the length of the cage on the side opposite the NB. Perches were 5 cm deep and 2.5 cm high. A metal dust bath (DB) measuring 60 cm wide and 20 cm deep was present in all cages and was made available for hen use in 12 randomly selected units (CWDB). To deter CWDB hens from nesting in the DB, the facility was opened daily at 1300 h, and was closed one hour before lights were turned off. Dust baths were filled with peat moss at opening, and since birds were inclined to consume this substrate, a small amount of peat moss was also deposited along the edge of the closed DB in the remaining 12 cages (CWODB). All colony units had solid metal sides. A total of 156 hens were housed in each of the CWDB and CWODB treatments (Figure 4.1).

In the above cage systems, all cage and NB floors were sloped at an angle of 7°. Manure removal was conducted twice weekly. Conventional and colony battery systems were purchased from Specht Canada, and modifications to the conventional units were carried out at the University of Alberta Poultry Research Centre. Although the floor space allowance of 450 cm^2 per bird was consistent between housing conditions, in the instance that one or more hens entered a nest box or dust bathing facility in MOD or the colony cages, floor space availability for hens remaining on the cage floor was increased.

4.3.3 Egg Production

In addition to quantifying total daily egg production per treatment group, per cage hen-day production and egg quality was assessed on 2 consecutive days every 4 wks, from 20 to 64 wks of age. Eggs were weighed fresh and stored for 4 days at 13°C. All eggs from CWDB and CWODB cages, and eggs from 30 randomly selected CONV and MOD cages were assessed for specific gravity using the flotation method (Hamilton, 1982). Eggs were then cracked, and shells with intact membranes were rinsed to remove albumen. Shells were dried overnight at room temperature, weighed and thickness was assessed using an Ames micrometer (Model 25, BC Ames Company, Waltham, MA).

4.3.4 Bone Quality

At 65 wks, hens were removed from their cages, weighed and euthanized via cervical dislocation. Right humerus, tibia and femur were excised, placed in individual plastic bags and stored at -20°C. Prior to analysis, bones from 20 randomly selected hens per treatment were thawed overnight and cleaned of all tissue. Bone mineral density and cross sectional area was assessed using quantitative computed tomography (QCT). Based on differences in bone mineral density, QCT permits distinction between cortical bone and bone in the trabecular space, which includes both trabecular and medullary bone mineral. QCT therefore provides an indication of structural bone condition (Korver et al., 2004). Using a Stratec XCT scanner (Model 922010, Norland Medical Systems, Inc., Fort Atkinson, WI) with XMENU software version 5.40C, bones were longitudinally scanned to set bone midpoints as the cross-sectional x-ray location. Cross-sectional analysis of a 1 mm bone section using threshold density values of 400 and 500 mg/cm^3 for trabecular and cortical bone separation, respectively (Korver et al., 2004), revealed total, cortical and trabecular bone densities and areas. Density and area measures were then multiplied to calculate the mass (mgQCT) of total and cortical bone, and bone in the trabecular space, for each 1 mm section.

Bone breaking strength analysis was conducted using an Instron Materials Tester (Model 4411, Instron Corp., Canton, MA) with Automated Materials Test System software version 8.09. Bones were cradled on two support points measuring 3 cm apart. Using a 50-kg load cell and a crosshead speed of 100 mm/min, the force of an attached shear plate measuring 8 cm in length and 1 mm wide was applied to the mid point of the same facial plane of each bone. Breaking strength was recorded.

4.3.5 Statistical Analysis

Humeral density and strength measures from one hen in each of CWODB and CONV treatments were excluded from calculated averages, since the humeral trabecular density values from these hens exceeded average treatment values by more than two standard deviations. Hens were the sample unit of measure and the cage was the experimental unit.

Response variables were analyzed for statistical significance using the GLM procedure (SAS Institute, 2002) and average bodyweight difference (BWDiff) as a covariate. BWDiff was calculated using the breeder's published 20 wk BW as the initial value, and the individual hen weight at 65 weeks as the final measure. When the effect of treatment was found to be significantly different, means were separated using the least significant means comparison. The following statistical model was used:

$$Y_{ij} = \mu + T_i + B(x_{ij}-\overline{x}) + e_{ij}$$

Where: Y = production variable

μ = overall mean

T = treatment; i = CONV, MOD, CWDB, CWODB

B = BWDiff; x_{ij}=j^{th} BW of i^{th} treatment; $\overline{x}$ = mean breeder BW

and e = the residual error [hen(treatment*BWDiff)].

Coefficients (r) for correlating bone quality (density, area and mass) and breaking strength with egg production (hen-day) and quality (stored egg mass, specific gravity, eggshell thickness and eggshell mass) measures were calculated using Pearson correlations (SAS Institute, 2002). Calculations were conducted both with treatments combined, to examine overall relationships in this strain of hen, as well as for individual housing treatments, to assess treatment effect. Unless otherwise stated, the level of significance for all statistical analyses was assessed at $P < 0.05$.

4.4 Results and Discussion

4.4.1 Bone quality and strength

4.4.1.1 Femur and tibia

Femoral and tibial total bone mineral density (BMD) and total bone mass (mgQCT) were significantly lower for CONV birds than for hens housed in CWDB and CWODB (Table 4.1). Since total cross sectional area did not differ between treatments, reduced CONV total density and mass measures were likely not attributable to smaller external bone diameter values. Similar total bone area would be expected since all birds in the current trial were of the same breed and age, and were raised under the same conditions during periosteal bone development. Fleming et al. (1994), who compared humeral radiographs of hens housed in conventional cages, a perchery, aviary or floor litter system, also observed consistent mean bone diameter values across housing conditions. The lower total BMD measure for CONV hens in the current study therefore likely reflects excessive bone mineral loss by birds whose movement was highly restricted.

Hens in the furnished systems were able to step onto and roost on a perch, move about the nest, and in the colony cages, could also jump up to and potentially bathe in the dust bath. Furthermore, the additional floor space available in the instance that one or more hens entered a nest box or dust bathing facility also permitted hens in furnished cages greater freedom of movement within the cage to perform behaviours such as wing and leg stretching, wing flapping, and sham dust bathing. In conventional cages, all of these activities are constrained by both the small surface area of the cage (Moinard et al., 1998) and the absence of a suitable amenity, and movement is likely insufficient to prevent loss of mineralized bone (Leyendecker et al., 2005; Vits et al., 2005).

The nature of this loss is further elucidated by cortical density, area and bone mass measures. In both the femur and the tibia, cortical bone density did not differ significantly between treatments (Table 4.1). However, cortical bone area was significantly lower in the femur of CONV hens as compared to CWDB or CWODB hens, and in MOD, the difference approached significance (P=0.07). CONV hens also exhibited significantly lower tibial cortical bone area than CWDB hens. In addition, the overall amount (mgQCT) of femoral cortical structural bone was significantly lower in CONV as compared to CWDB, CWODB and MOD, and in the tibia, CONV hens had significantly lower bone mass than CWDB and CWODB hens (Table 4.1). These findings suggest that while the density of remaining femoral and tibial cortical bone was similar for birds in the different cage systems, the width of the remaining cortex in these bones was narrowest for conventionally-housed birds, and the overall amount of cortical bone was also lowest in CONV. Fleming et al. (1994) attributed increased humeral cortical thinning in conventionally-caged hens to excessive bone resorption from endosteal surfaces. Presumably then, in the current study, CWDB, CWODB and, to some extent, MOD birds, who had increased opportunity for movement and bone loading, were better able to protect femoral and tibial cortical structural bone from endosteal surface erosion than hens in CONV cages.

The trabecular space, as defined for QCT analysis, is comprised of both trabecular and medullary bone mineral (Korver et al., 2004), and changes in trabecular measures are likely representative of changes in medullary bone (Riczu et al., 2004). In the present study, density of bone in the trabecular space was highest for CONV hens (Table 4.1), with the difference approaching significance in the femur of CWODB (P=0.07) and MOD birds (P=0.07), and in the tibia of CWDB (P=0.09) and MOD (P=0.07) hens. Cross sectional area of bone in the trabecular space was also highest in CONV, and the difference was significant for the femoral CWDB value, and approached significance for femoral CWODB (P=0.08) and tibial CWDB (P=0.07) averages. Taken together with the significantly lower cortical bone area values for CONV birds, these findings support the above suggestion that hens in conventional cages were least successful at preventing cortical structural bone resorption. CONV birds likely mobilized more cortical bone, but less medullary bone than hens who had greater opportunity for movement and load-bearing activity, resulting in increased cortical thinning, but a higher density of bone in the trabecular space. Since a greater reduction in the width of the cortex is accompanied by a greater corresponding increase in the diameter of the trabecular or marrow space (Fleming et al., 1994), femoral trabecular area was also higher in CONV than in CWDB cages, as was the overall amount of bone in the trabecular space (mgQCT). In contrast, birds in CWDB and CWODB cages appeared to efficiently mobilize calcium from femoral medullary bone, thereby protecting their structural cortical bone, and resulting in higher cortical area and mass values than in CONV, but reduced trabecular area and bone mass (mgQCT).

It is interesting to note that in the femur, density of bone in the trabecular space was higher for CWDB than CWODB or MOD hens and the difference approached significance (CWODB: P=0.08; MOD: P=0.09). This suggests that additional opportunity for bone loading through access to the raised dust bath may have contributed to reduced net loss of bone in the trabecular space, as well as having encouraged protection of cortical bone. Since a negative correlation has been determined between medullary and trabecular bone turnover (Rennie et al., 1997), encouraging medullary bone remodeling might therefore minimize trabecular bone loss. In addition, Riczu et al. (2004) proposed that improved bone quality observed in brown-egg strain layer hens over white-egg strain birds may have resulted from the ability of brown-egg hens to both target and replenish medullary calcium reserves, thereby offering increased protection of cortical bone. In the present study, additional movement by CWDB hens may therefore have prevented excessive loss of trabecular and cortical structural bone by encouraging both the mobilization and replenishment of medullary calcium reserves. Passi and Gefen (2005), who demonstrated significant reductions in the mediolateral impact energy required to fracture femurs from which core trabecular tissue had been extracted, suggested that trabecular bone serves an important role in distributing applied impact loads to the cortex, and that minimizing trabecular bone loss might therefore be equally important in the prevention of osteoporosis, as is minimizing loss of cortical bone. Allowing caged hens access to a raised dust bath, as well as a nest site and perch, may therefore have important consequences for preventing osteoporosis by protecting both trabecular and cortical structural bone.

The significantly lower cortical and significantly higher trabecular area in CONV also clarifies why CONV hens exhibit significantly lower total bone density, in spite of having comparable cortical and trabecular density values. The total bone diameter of CONV birds is comprised of a large area of lower density bone in the trabecular space, and a thin band of higher density, compact cortical bone. In contrast, colony cage and MOD hens have a thicker band of higher density cortical bone and a smaller area of lower density bone in the trabecular space. Total bone density is therefore likely to be higher for birds with a thicker cortex.

Overall, in the femur and tibia of hens from the cage systems examined, conventionally-housed birds exhibited the lowest cortical cross sectional area, suggestive of increased cortical thinning, the highest trabecular density, likely associated with reduced efficiency of medullary bone resorption, and the highest cross sectional area of bone in the trabecular space, likely resulting from their increased marrow space. Taken together, these results suggest greater loss of structural bone for hens in conventional cages than for birds in furnished systems. Since persistent cortical thinning can lead to osteoporosis (Bell and Siller, 1962) and increased susceptibility to bone fracture (Whitehead and Fleming, 2000), even when medullary stores may be increasing (McCoy et al., 1996), it could therefore be expected that structurally, bones from conventionally-housed birds would be weaker. In the current study, breaking strength values were significantly lower in the femur and tibia of birds in conventional cages than for colony birds (Table 4.2). Breaking strength was highest for CWDB birds, followed by CWODB hens, as might be anticipated since hens in CWDB cages experienced the greatest freedom of movement and opportunity for bone loading. Significantly enhanced tibial strength has also been previously demonstrated for hens housed in conventional cages containing a perch (Hughes and Appleby, 1989; Duncan et al., 1992), furnished cage systems containing perches, nest boxes and dust bathing facilities (Leyendecker et al., 2005), and non-cage systems such as aviaries, percheries and floor litter systems (Rowland et al., 1968; Rowland and Harms, 1970; Knowles and Broom, 1990; Norgaard-Nielsen, 1990; Fleming et al., 1994; Abrahamsson and Tauson, 1995; Newman and Leeson, 1998; Leyendecker et al., 2005), as compared to conventionally-caged hens.

4.4.1.2 Humerus

In the laying hen, the humerus is normally a pneumatized bone, devoid of mineral in the trabecular space. Varying degrees of humeral pneumatization have however been previously reported (Hogg, 1984; Fleming et al., 1996), and the presence of medullary bone appears to increase humeral density and bone strength (Fleming et al., 1996; 1998). In the present study, bone in the trabecular space was detected in the humerus of one CWODB hen and one CONV hen. Since humeral trabecular density values from both of these hens exceeded average trabecular density values of the respective treatments by more than two standard deviations, these values were considered outliers, and humeral density and strength measures from the two hens were excluded from calculated averages (Fleming et al., 1994).

Total humeral mineral density and bone mass were significantly higher for CWDB and CWODB hens than for CONV and MOD birds, and, as observed in the femur and tibia, total bone area did not differ between housing conditions (Table 4.1). In the absence of bone in the trabecular space, total humeral bone measures would be expected to reflect the condition of the cortex. Indeed, cortical density and bone mass (mgQCT) were significantly higher for CWDB and CWODB hens than for birds in CONV or MOD cages. In addition, cortical area values were significantly higher for hens in colony cages than hens in CONV and MOD. Taken together, these findings point to increased humeral cortical thinning for birds with reduced opportunity for wing movement. Fleming et al. (1994) also observed increased humeral cortical thinning for conventionally-caged layers as compared to non-caged hens. Furthermore, the significantly lower cortical density values of CONV and MOD hens suggests that in addition to greater cortical bone loss from the endosteal surface, in the pneumatic humerus, bone loss occurring at exposed mineral sites throughout the cortex was advanced when birds had limited wing movement.

Whitehead and Fleming (2000) proposed that decreased humeral density, as measured by radiographic analysis, is indicative of osteoporosis, and Hester et al. (2004) demonstrated a positive correlation between bone radiographic density and humeral breaking strength. Humeral breaking strength values in the current study would therefore be expected to reflect total and cortical density measures. Bone strength measures were in fact, significantly higher for hens housed in the colony cages than for birds in CONV or MOD cages, and were highest for CWDB hens (Table 4.2). Enabling caged birds to perform activities such as jumping up to the raised dust bath and dust bathing therefore encouraged humeral cortical bone protection and increased bone strength. In addition, bouts of wing movement including flapping, stretching and ruffling were observed to be less restricted in the colony cages than in CONV and MOD, and likely further contributed to increased humeral strength of CWDB and CWODB hens. Abrahamsson et al. (1996) and Leyendecker et al. (2005) also demonstrated significantly higher humeral bone strength for hens housed in furnished cage systems than hens in conventional battery cages, and increased humeral breaking strength has been observed for hens housed on floor litter, in perchery or in aviary systems, as compared to hens maintained in conventional cages (Knowles and Broom, 1990; Norgaard-Nielsen, 1990; Fleming et al., 1994; Abrahamsson and Tauson, 1995).

It appears that humeral cortical bone protection was not afforded by perching activity in MOD. Abrahamsson et al. (1996) observed a numerical increase in humeral bone strength when hens in conventional cages were provided with a perch, and suggested that the wing movement performed by hens to elevate themselves onto the perch contributed to increased bone strength. Notably, hens in that trial each had access to 600 cm^2 floor space, considerably more room for wing movement than hens in the current study. Moinard et al. (1998) however, demonstrated that increasing cage height, not area, was necessary to significantly increase humeral strength of conventionally-caged hens. The authors attributed this improvement to the higher frequency of comfort wing stretching and flapping displayed by hens in taller cages.

In summary, hens in CWDB cages were best able to protect humeral structural bone. CWODB hens also exhibited improved humeral condition, however birds in MOD cages were unable to maintain humeral cortical bone through perching activity. Enabling hens access to a raised amenity, and providing hens with the opportunity to dust bathe and increase their wing movement was necessary to minimize cortical structural bone resorption both at the endosteal surface and throughout the cortex, and thereby improve humeral bone quality. Since fracture incidence in laying hen bones are highest in the humerus (Gregory and Wilkins, 1989), improving humeral cortical bone quality and reducing fracture rates in caged hens by inclusion of adequate amenities and space has considerable implications for hen welfare and production.

4.4.2 Correlation

4.4.2.1 Treatments Combined - Egg Production/Quality Parameters and Bone Quality/Breaking Strength Measures

With the exception of a minimally positive correlation between hen-day production and humeral cortical density (r=0.37, P=0.003), overall, no strong correlations were found between egg production and bone quality parameters for the combined treatment values. Since production did not differ significantly between treatments (Chapter 5), the absence of correlation suggests that egg production in general was maintained irrespective of bone quality for this high-producing strain of bird. Superior bone quality measures observed for hens housed in furnished cages are therefore not the result of lowered egg production and consequent reduced calcium requirement, but rather are attributable to the protective effect of activity on cortical bone. Whitehead et al. (1998) demonstrated that concomitant high egg production and good bone quality are possible at the end of lay, and Rowland et al. (1972) observed no relationship between tibial breaking strength and egg production, suggesting that superior bone strength and egg production measures may be observed simultaneously. Rennie et al. (1997) demonstrated minimal relationships between trabecular bone volume and egg production in both free thoracic vertebrae and proximal metatarsus bones of highly productive Hisex birds, even though the majority of those hens were osteoporotic at the end of lay. The authors however, attributed the development of osteoporosis to the length of the period of continuous egg production, rather than to hen-day production. Inclusion of amenities that provide continuously-producing caged laying hens with opportunity for movement and load-bearing exercise may therefore be of utmost importance in deterring the onset of osteoporosis.

Few correlations were observed between measures of egg quality and bone density or breaking strength further suggesting that overall, observed treatment differences in bone parameters were not influenced by treatment differences in egg quality.

4.4.2.2 Individual Treatments - Egg Production/ Quality Parameters and Bone Quality/Breaking Strength Measures

In the femur of CWDB and CWODB hens, a significant negative correlation (CWDB: r=-0.60, P=0.04; CWODB: r=-0.60, P=0.05) was observed between egg production and trabecular density. A reduction in trabecular density that accompanies an increase in production, and hence an increased calcium requirement, is consistent with the suggestion that egg production in active birds is likely maintained by resorption of medullary bone in the trabecular space, rather than at the expense of cortical bone. Indeed, this correlation was not apparent for CONV or MOD hens, who had less opportunity for load-bearing activity.

A positive significant correlation between eggshell weight and total bone density was observed in the femur (r=0.65, P=0.02), and between eggshell weight and breaking strength in both the femur (r=0.70, P=0.01) and tibia (r=0.81, P=0.001) of CWDB birds. In contrast, Riczu et al. (2004), observed negative correlations between eggshell weight and total femoral density, which the authors attributed to calcium mobilization from bone reserves to support eggshell formation. In the present study, the positive relationship between these two parameters suggests that for CWDB hens, caged birds with the greatest opportunity for activity, structural bone reserves were protected, and therefore overall bone quality was not compromised by high egg quality. Notably, in the tibia of CWDB hens, a significant negative correlation was found between specific gravity and trabecular area (r=-0.75, P=0.005), and the relationship approached significance in the femur (r=-0.56, P=0.06). This would suggest that the quality of the egg increased with decreasing area of bone in the trabecular space, or, with reduced endocortical thinning. Taken together, these findings further support the intimation that for caged hens with sufficient opportunity for load-bearing activity, shell formation is maintained by improved mobilization of medullary bone from the trabecular space, rather than at the expense of cortical bone.

In contrast to CWDB hens, CWODB birds exhibited a negative significant correlation between eggshell weight and breaking strength in the femur (r=-0.66, P=0.03), a correlation that approached significance in the tibia (r=-0.54, P=0.08). Perhaps CWODB hens, who experience less opportunity for mechanical bone loading than CWDB birds but greater opportunity than MOD or CONV hens, are able to minimize structural bone loss, but compared to CWDB hens, have a lowered capacity to mobilize medullary calcium reserves for eggshell formation. Bishop et al. (2000) report decreased shell quality in bird lines that are more resistant to osteoporosis. CWODB hens also demonstrated a significant positive correlation between stored egg weight and trabecular density in the femur (r=0.74, P=0.01) and in the tibia (r=0.81, P=0.002), as well as between eggshell weight and trabecular density (femur: r=0.60, P=0.05; tibia: r=0.70, P=0.02), providing additional evidence that to support eggshell formation, CWODB hens source calcium reserves from medullary bone, rather than sacrifice structural bone.

A negative significant correlation between trabecular density and eggshell thickness (r=-0.54, P=0.01), and a positive significant correlation between eggshell weight and cortical area (r=0.44, P=0.05) observed in the femur of CONV hens, provides additional evidence that both medullary and structural bone are mobilized to support eggshell formation when hens have little opportunity for load-bearing movement. Significant positive correlations between stored egg weight and total bone area were observed in the tibia of MOD hens (r=0.53, P=0.01) and the femur of CONV birds (r=0.46, P=0.04), as well as between stored egg weight and trabecular area (r=0.45, P=0.04), and eggshell weight and total bone area (r=0.53, P=0.02) in the tibia of MOD hens. Stored egg weight and total area were also positively correlated (r=0.45, P=0.05) in the humerus of CONV hens. These results likely reflect the tendency for larger hens to lay larger eggs.

The findings from this study provide evidence that movement and load-bearing exercise increase bone strength by enabling caged hens to efficiently mobilize medullary bone and to preserve cortical structural bone. Additional bone preservation in the form of medullary remodeling may also occur in the trabecular space, as noted for CWDB hens. In addition, providing caged hens with a raised amenity, and the opportunity to dust bathe and increase their wing movement is necessary to maintain humeral architecture. With the knowledge that exercise has a protective effect on cortical bone, and with the technical means to examine cortical bone in live birds via QCT analysis, management practices, such as inclusion of appropriate amenities in cage systems, should therefore be explored and adopted to encourage structural bone preservation in laying hens. Genetic selection for heritable cortical bone traits associated with bone strength can also be further directed. Bishop et al. (2000) for example, have already demonstrated that bone strength characteristics are moderately to strongly heritable and respond to selection for cancellous and medullary bone traits.

Additional studies will be necessary to quantify and qualify the nature of and extent to which hen structural bone can be protected through mechanical strain. From the present study however, it is clear that for hens housed in cage systems, structural bone protection is afforded when amenities and space are available to permit sufficient movement and load-bearing exercise. These findings have considerable implications for laying hen welfare and production.

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4.6 Tables and Figures

Table 4.1 Femur, humerus and tibia quality of 65 wk old White Leghorns housed in colony, conventional and modified cages.

		Density			Area			Mass per 1-mm Section^{1}		
Bone Type and Housing^{2}	n^{3}	Total (mg/cm^{3})	Cortical (mg/cm^{3})	Trabecular (mg/cm^{3})	Total (mm^{2})	Cortical (mm^{2})	Trabecular (mm^{2})	Total (mgQCT)	Cortical (mgQCT)	Trabecular (mgQCT)
Femur										
CWDB	20	785.44^{a}	944.06	260.05	40.39	28.99^{a}	5.47^{b}	31.64^{a}	27.96^{a}	1.57^{b}
CWODB	20	763.75^{ab}	945.72	225.45	41.83	29.37^{a}	6.60^{ab}	31.89^{a}	27.97^{a}	1.63^{b}
CONV	20	672.21^{c}	985.93	261.69	40.32	22.87^{b}	11.50^{a}	27.02^{b}	20.75^{b}	3.27^{a}
MOD	20	710.63^{bc}	953.96	226.70	41.69	28.17^{ab}	10.23^{ab}	29.59^{ab}	25.40^{a}	2.57^{ab}
SEM		38.60	33.64	20.17	1.01	2.97	2.84	1.59	2.35	0.78
					Probabilities					
Housing		0.0194	0.5693	0.1011	0.2500	0.1089	0.1149	0.0103	0.0086	0.1002
Humerus										
CWDB	20	216.20^{a}	1109.05^{a}	-^{4}	39.86	10.79^{a}	27.69^{b}	8.53^{a}	12.13^{a}	-
CWODB	19	195.36^{a}	1095.27^{a}	-	40.51	10.36^{a}	28.76^{b}	7.83^{a}	11.47^{a}	-
CONV	19	153.69^{b}	1048.90^{b}	-	39.91	9.30^{b}	28.80^{ab}	6.07^{b}	9.59^{b}	-
MOD	20	141.33^{b}	1042.53^{b}	-	43.08	9.13^{b}	31.84^{a}	5.92^{b}	9.48^{b}	-
SEM		19.01	16.05	-	1.97	0.42	1.77	0.66	0.51	-
					Probabilities					
Housing		0.0003	<0.0001	-	0.2686	0.0001	0.0873	0.0003	<0.0001	-
Tibia										
CWDB	20	832.10^{a}	1037.38	220.20	32.16	23.02^{a}	6.07	26.72^{a}	24.40^{a}	1.36^{b}
CWODB	20	809.36^{b}	1049.06	235.49	32.32	21.72^{ab}	6.86	26.12^{a}	23.05^{ab}	1.64^{ab}
CONV	20	735.98^{c}	1057.35	246.04	31.81	19.41^{b}	9.45	23.32^{b}	19.36^{c}	2.40^{a}
MOD	20	755.04^{bc}	1037.48	218.94	32.54	21.44^{ab}	8.84	24.44^{ab}	21.39^{bc}	1.94^{ab}
SEM		35.97	28.58	15.27	0.71	1.79	1.82	1.06	1.47	0.45
					Probabilities					
Housing		0.0304	0.8644	0.2100	0.7453	0.2490	0.2103	0.0076	0.0074	0.1343

$^{a-c}$Means within the same column and bone type lacking a common superscript differ significantly ($P<0.05$). ^{1}QCT = Quantitative Computed Tomography.

^{2}CWDB = furnished colony cage with dustbath; CWODB = furnished colony cage without dustbath; CONV = conventional cage; MOD = modified cage.

^{3}Number of bones assessed. ^{4}Note: the average trabecular density for all but one humerus in CWODB and one humerus in CONV was 0 mg / cm^{3}.

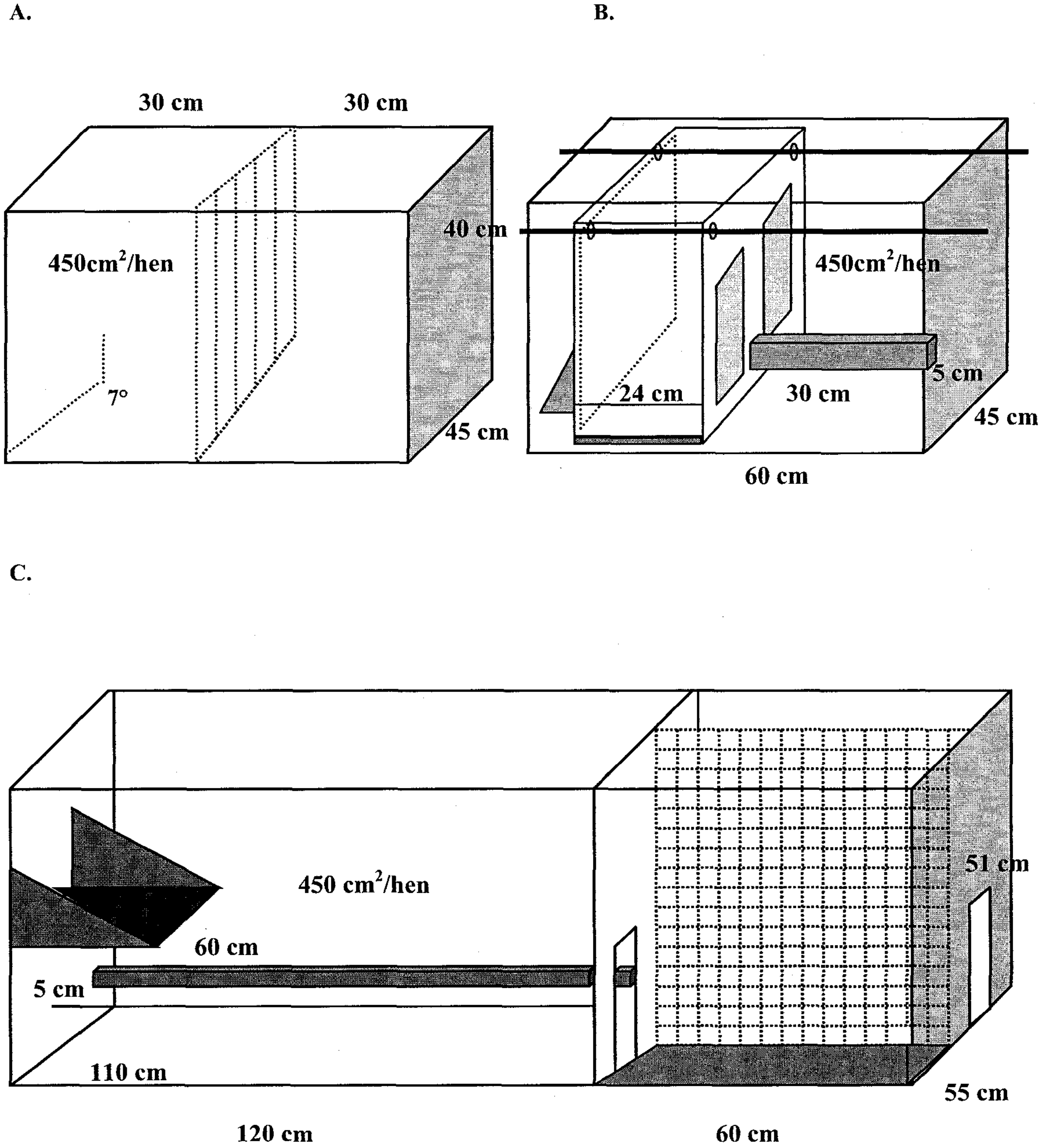
Table 4.2 Femur, humerus and tibia breaking strength of 65 wk old White Leghorns housed in colony, conventional and modified cages.

		Breaking Strength (kgf)			
	Femur		Humerus		Tibia
CWDB	29.59^{a} (20)^{1}	CWDB	13.67^{a} (20)	CWDB	28.62^{a} (20)
CWODB	27.07^{ab} (20)	CWODB	11.91^{a} (19)	CWODB	27.66^{a} (20)
CONV	21.92^{c} (20)	CONV	9.73^{b} (19)	CONV	21.96^{b} (20)
MOD	24.55^{bc} (20)	MOD	8.69^{b} (20)	MOD	24.48^{b} (20)
SEM	2.42	SEM	0.83	SEM	1.70
			Probabilities		
Housing	0.0158		<0.0001		0.0007

$^{a-c}$Means within the same column and bone type lacking a common superscript are significantly different ($P<0.05$).

^{2}Means are followed by n values given in parentheses.

Figure 4.1 Housing treatments. A: The Conventional cage (CONV). B: The Modified cage (MOD). C: The Furnished Colony cage with Dust Bath (CWDB).



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Chapter 5

An Evaluation of Physical Condition and Production of Laying Hens Housed in Conventional, Modified and Furnished Colony Cage Systems

This chapter has been prepared in the format of the scientific journal Poultry Science and has been submitted to the Journal for review.

5.1 Abstract

Welfare and productivity of caged White Leghorns were evaluated by assessing hen physical condition and performance. Beak-trimmed, floor-litter reared hens were housed in conventional cages (CONV), conventional cages modified to incorporate a nest box and perch (MOD), or commercially-available, furnished colony cages containing a nest box, perch and dustbath. In half of the colony cages, the dustbath was opened daily at 1300h and filled with peat moss (CWDB). In the remaining colony units, the dustbath was kept closed (CWODB). Hens were assessed for plumage, foot and claw condition, keel bone deformation, and comb/wattle and tail/cloaca wounds. Egg production and quality, proportion cracked and dirty eggs, feed consumption and conversion efficiency, and bird live weight and mortality were also examined.

Feather condition scores for hen overall and individual body region were lower in colony cages than in CONV or MOD, however CWDB showed improved feather condition over CWODB. MOD hens demonstrated improved regional feather condition over hens in CONV, and improved foot condition and fewer comb/wattle wounds than all other birds. Egg productivity did not differ between cage environments, however hens clearly preferred to oviposit in the nest boxes provided, and dustbath laying and consequent egg soiling were low due to use of a timed closing mechanism. Increased egg cracking was observed when eggs were allowed to accumulate in the egg tray in front of the nest box, but overall eggshell quality was improved in colony systems. Birds in CONV and MOD had lower feed energy requirements and higher body weights than

CWDB and CWODB hens, and mortality did not differ between cage treatments, despite increased incidence of cannibalism-related deaths in CWODB.

The findings from this study provide evidence that provision of nesting, perching and dustbathing facilities in cage environments improves hen welfare and productivity parameters. However additional studies evaluating optimal group size and strain suitability for large group cage housing are necessary.

5.2 Introduction

Conventional battery cages for laying hens provide economic benefits for egg producers (Cooper and Albentosa, 2003), and offer hens a hygienic and small group housing environment (Duncan, 2001). It is however widely acknowledged that there are serious concerns regarding the quality of life of birds housed in these systems (Nicol, 1987; Baxter, 1994). The barren environment of the cage prevents the performance of ethological needs (Mench, 1992), and space limitations impose severe restrictions upon movement and escape from aggression (Appleby et al., 1992). As of 2012, the European Union will prohibit conventional cage housing, and only cages that offer increased cage area and height, and that are furnished with nesting, perching and litter facilities and claw abrasive devices will be further permitted (CEC, 1999).

Although conventional cages currently remain the predominant housing system for laying hens in North America, in the future, North American egg producers may also begin the transition to production in furnished cage designs that maintain the benefits of cage systems, yet provide amenities that permit the expression of natural behaviour and increase hen space and opportunity for movement (Appleby, 2003). Two such potential designs are modified cages and commercially-available, furnished colony systems. Modified cages enable producers to minimize new investment costs by incorporating furnishings into existing small group cage capital, whereas commercial large group cages aim to minimize capital costs by maximizing hens housed per furnished cage area (Wall et al., 2004).

To assess the impact of housing environment on laying hen welfare, multiple indices of hen physical and physiological condition, behaviour and performance are typically investigated (Weitzenburger et al., 2005; Nicol et al. 2006). Feather scoring to evaluate plumage condition, has been shown to serve as a reliable and alternative, or complementary measure of hen production and behavioural traits, including feather pecking activity (Tauson et al., 1984; Bilčík and Keeling, 1999). Additional evaluation of integument, foot condition, mortality, egg production, quality and hygiene, and hen feed consumption and conversion efficiency are further indicative of bird health and welfare, and may reveal potential problems with or advantages to cage design and conditions (Tauson et al, 1984; 2006; Appleby and Hughes, 1991; Tauson, 1985; Nicol et al., 2006).

The objective of this study was to assess the welfare of caged Shaver White Leghorn hens housed in conventional, modified and commercially available, furnished cage systems by evaluating measures of hen physical condition and performance. Additional studies which have been conducted to further assess behavioural and physiological indices of hen welfare and productivity have been presented in Chapters 2, 3 and 4.

5.3 Materials and Methods

5.3.1 Housing Systems

This research was carried out in accordance with the Canadian Guide to the Care and Use of Experimental Animals (CCAC, 1993). The experimental protocol was authorized by the Faculty Animal Policy and Welfare Committee at the University of Alberta. A detailed description of the four cage designs and experimental animals was presented in Chapter 4 (Jendral et al., 2008). Briefly, 1 d old hot-blade beak trimmed White Leghorn (Pacific Pride Chicks, Abbotsford, BC, Canada) layer chicks originating from Shaver parent breeder stock were raised in floor pens (at a stocking density of 50 birds per pen). Birds were provided with ad libitum access to feed and water throughout the trial and were hand fed a standard commercial layer diet in accordance with NRC requirements and primary breeder recommendations. Day length was gradually increased from 10 hours (0700 to 1700) to 14 hours (0500 to 1900) between 20 and 24 wks. From 30 wks to the end of the trial, one additional hour of light was introduced between midnight and 0100 h. Feed was top dressed twice weekly with 3 g oyster shell per bird from 32 to 39 wks, and 6 g oyster shell per bird per wk from 39 to 65 wks. Manure belts were cleaned twice weekly.

At 19 wks, birds were randomly allocated to one of 4 cage treatments. A total of 84 conventional cages (CONV) measuring 30 cm wide, 45 cm deep and 40 cm high at the rear, each housed 3 birds, providing each of the 252 hens with 450 cm^2 of floor space. Modified cages (MOD), developed from standard 60 cm X 45 cm X 40 cm conventional cages, incorporated a wooden nest box measuring 24 cm wide, 45 cm deep, and 35 cm high at the rear, a 30 cm long softwood perch, and a lightweight door that closed nightly. Each of the 84 MOD cages housed 3 hens, providing each of the 252 MOD birds with 450^2 cm of floor space and an additional 360 cm^2 of nest space during the day. Nest boxes were placed on the same side of each MOD cage, thereby creating solid cage sides between neighboring units. Hens in the third and fourth cage treatments were housed in 24 Parent Stock cage systems (Specht Canada, Stony Plain, AB, Canada). These colony housing units measured 120 cm wide, 110 cm deep and 51 cm high at the center, contained a 60 cm wide X 55 cm deep metal nest box, a 120 cm long softwood perch, and provided 26 hens each with 450 cm^2 of floor space and 126 cm^2 nest area. Colony cages were also equipped with a metal dustbath measuring 60 cm wide and 20 cm deep, and all colony units had solid metal sides. In 12 cages (CWDB), the dustbath was opened daily between 1300 and 1800 h and was filled with peat moss. For the remaining 12 cages (CWODB), the dustbath was not opened, but birds could jump up to and perch on the edge of the closed amenity. Since hens in CWDB were inclined to consume peat moss, a small amount of the substrate was also deposited along the edge of the closed dustbath in CWODB cages.

5.3.2 Physical Condition

The exterior appearance of all hens in 30 randomly selected CONV and MOD cages, and in 12 CWDB and 12 CWODB cages was evaluated at 31 and 65 wks, and average cage scores were calculated. Plumage, foot and claw condition were assessed using the 4 point scoring system described by Tauson et al. (1984) and Tauson (1984), with 4 representing the best possible score (Table 5.1). Feather scores were evaluated for seven discrete regions of the body including the head and neck, breast, belly, back, wings, tail and vent area (Tauson et al., 1984; Bilčík and Keeling, 1999). Total body feather score was calculated by summing individual body region values. The maximum possible total score for a hen was therefore 28 while the minimum possible value was 7. For each hen, the condition of both feet and both claws was evaluated separately, and an average score was then calculated per hen, and per cage. Feet were assessed for toe pad hyperkeratosis as well as bumblefoot. Keel bone deformation, and wounds (pecks or scratches) on the comb and wattles, and around the tail and cloaca were also evaluated and assessed on a scale from 4 (no deformities; no injuries) to 1 (severe deformities; multiple wounds or wounds >2cm in diameter). At each assessment period, scoring was carried out by two groups of two individuals including a recorder and a trained scorer. Scorers were unaware of the treatment group from which the hens originated. To ensure maximum scoring consistency, equal numbers of hens from each treatment were scored by each of the 2 evaluating groups.

5.3.3 Productivity

Total daily egg production from 19 to 65 wks was recorded for each treatment, without cage identification, to determine HH (eggs laid per cage x 100/ # of hens housed per cage at 19 wks) and HD productivity (eggs laid per cage x 100/ # of original hens housed per cage at time of recording). On two consecutive days every 4 wks from 20 to 64 wks, all eggs from CWDB and CWODB, and eggs from 30 randomly selected CONV and MOD cages were assessed for location of lay, percentage cracked and dirty eggs, and egg and eggshell quality. For the two consecutive collection days at wks 40 and 44, two alternative, manual collection techniques were tested to determine whether egg accumulation in the egg cradle, and resultant egg collision, affected the proportion of cracked, nest-laid eggs. On the first day, eggs were collected as per normal, in the early afternoon, after the majority of eggs had accumulated in the egg tray. On the second day, eggs from all cages were collected as soon as they rolled onto the egg tray, to simulate the effect of a conveyer system, and thereby minimize egg collisions. For all collections between 20 and 64 wks, eggs were weighed and analyzed for cracking and cleanliness using a hand-held egg-candling device. After 4 days storage at 13°C, undamaged eggs were equilibrated to room temperature and assessed for specific gravity using the flotation method (Hamilton, 1982). Specific gravity provides a measure of the amount of shell present relative to the size of the egg (Roberts, 2004). Eggs were then cracked and rinsed to remove albumen. Shells with intact membranes were dried overnight at room temperature, weighed and thickness was assessed using an Ames micrometer (Model 25, BC Ames Company, Waltham, MA). Percentage shell was calculated as [(dry eggshell weight/egg weight) x 100].

Total feed consumed (g feed/hen/day) was measured for all 12 CWDB and 12 CWODB cages and for 30 randomly selected CONV and MOD cages at 26, 27, 28 and 64 wks. Birds were fed by hand once per day during. Feed conversion efficiency (g feed/g eggs) was also assessed at 28 and 64 wks. Live weight was recorded for all hens at 65 wks, and mortality was recorded throughout the trial. With the exception of birds who were euthanized for obvious reasons such as bone breaks or cannibalism, all mortalities were subject to necropsy. Total mortality was expressed as percent of hens housed.

5.3.4 Statistical Analyses

For hen condition data, egg quality measures (egg weight, specific gravity, shell thickness, shell weight) and feed intake data, average cage scores were tested for normality and transformed as required. Treatment and time effects were analyzed using the repeated measures MIXED procedure (SAS Institute, 2002), with age as the repeated variable, and differences were assessed using Fisher's protected least-significant differences test. The following statistical model was used:

$$Y_{ijk} = \mu + T_i + C_{(j)i} + A_k + TA_{ik} + e_{j(ik)}$$

Where: Y = production variable

μ = overall mean

T = treatment; i = CONV, MOD, CWDB, CWODB
C = cage; j = randomly selected cages (nested within treatment)
A = age; k = age at which data collected
and e = the residual error [hen(treatment*cage*age)].

Prior to statistical analysis, production variables expressed as proportions were first subjected to arcsine transformation. Traits that were accumulated prior to analysis (HH and HD productivity, location of lay, cracking and cleanliness, mortality) or measured once (live weight) were analyzed using the MIXED procedure of SAS, and means separation by least significant means comparison. The following statistical model was used:

$$Y_{ijk} = \mu + T_i + C_{(j)i} + e_{j(i)}$$

Where: Y = production variable
μ = overall mean
T = treatment; i = CONV, MOD, CWDB, CWODB
C = cage; j = randomly selected cages (nested within treatment)
and e = the residual error [hen(treatment*cage)].

The level of significance for all statistical analyses was assessed at $P \leq 0.05$.

5.4 Results

5.4.1 Plumage Condition

5.4.1.1 Total

As revealed from the repeated measures analysis, average total feather condition score differed significantly among treatments ($P<0.0001$) and decreased with age ($P<0.0001$) (Table 5.2). At 31 wks, total feather score was higher in CONV and MOD than in CWODB ($P<0.0001$ and $P=0.0001$, respectively) and was higher in CONV than in CWDB (P=0.02). Hens in CWDB exhibited higher total plumage scores than hens in CWODB (P=0.05).

By 65 wks, total feather score was higher for CONV hens than for birds in CWDB (P=0.05) or CWODB (P<0.0001)), and was also higher in MOD than in either CWDB (P=0.01) or CWODB (P<0.0001). CWDB birds also had a higher total feather score than birds in CWODB (P=0.05).

5.4.1.2 Individual regions

Average feather condition scores were found to differ significantly among treatments for the head/neck (P<0.0001), back (P<0.0001), wings (P=0.001), vent, breast and belly regions (P<0.0001), but not for the tail region (P=0.06) (Table 5.2). For all cage systems and all individual regions, average feather score decreased with age from 31 to 65 wks (P<0.0001).

Head/neck feather score values were significantly higher for hens in MOD and CONV at 31 wks than in either CWDB or CWODB (P<0.0001), and at 65 wks, MOD and CONV scores were higher than CWODB (P=0.0003 and P=0.003, respectively) (Table 5.2).

At 31 wks, feather condition of the back region was improved in MOD over CWDB (P=0.008) and CWODB (P<0.0001), and was also superior in CONV than in CWDB (P=0.002) or CWODB (P<0.0001) (Table 5.2). Similar treatment differences were observed at 65 wks with both MOD and CONV hens having higher scores than birds in CWDB (P=0.0001 and P=0.001, respectively) and CWODB (P<0.0001).

No treatment differences were observed for wing feather scores at 31 wks (Table 5.2). However, by 65 wks, wing condition was superior for birds in MOD than in CONV (P<0.0001) and CWODB (P=0.001). CONV hens also exhibited lower scores than birds in CWDB (P=0.003). Tail feather scores were lower for hens in CWODB than in CONV

(P=0.05) and MOD (P=0.02) at 31 wks, and lower in CWODB than in MOD (P=0.05) at 65 wks.

At 31 wks, vent plumage condition was significantly higher in MOD than in CWDB (P=0.02) and CWODB (P<0.0001), in CONV than in CWDB (P=0.01) and CWODB (P<0.0001), and in CWDB than in CWODB (P=0.0002) (Table 5.2). By wk 65, vent feather scores were similar in MOD, CWDB and CWODB, but higher for hens in CONV than in MOD (P<0.0001), in CWDB (P=0.0005) and in CWODB (P<0.0001).

Breast feather cover was lower in CWODB than in CONV (P=0.002) and MOD (P=0.002) at 31 wks (Table 5.2). By wk 65, feather condition was higher in MOD than in CONV (P=0.02), CWDB (P=0.002) and in CWODB (P<0.0001). CONV hens also had higher plumage scores than CWODB hens (P=0.002).

At both 31 and 65 wks, belly feather covering was superior in CONV than in MOD (P=0.04 and P=0.02, respectively), CWDB (P=0.001 and P<0.0001, respectively) and CWODB (P<0.0001) (Table 5.2). MOD hens had better belly feather cover than CWDB hens at 65 wks (P<0.0001), and better cover than CWODB hens at wks 31 and 65 (P=0.0002 and P<0.0001, respectively).

Treatment effect was found to be significant for average foot and claw condition scores (P=0.01 and P=0.05, respectively), and both scores decreased with age (P=0.03 and P<0.0001, respectively) (Table 5.3). Foot condition declined in CONV from 31 to 65 wks (P=0.04), and claw condition deteriorated over time for all treatments (P<0.0001).

At 31 wks of age, no differences in foot or claw condition were apparent between cage systems (Table 5.3). However, by 65 wks, foot condition was superior for hens in MOD cages than in CONV (P=0.03) and CWDB (P=0.01). At 65 wks, claw condition scores were also higher in MOD than in CONV (P=0.01) and CWDB (P=0.02). Bumblefoot was not observed in any of the cage treatments at either 31 or 65 weeks.

Differences in scores for wounds to the comb/wattle were found to be significant among treatments (P<0.0001), as was the overall age effect (P<0.0001), with scores declining from 31 to 65 wks for CWDB and CWODB (P<0.0001) (Table 5.3). At 31 wks, MOD hens showed superior wound/comb condition over hens in CONV (P=0.0015). By wk 65, wounds to the comb/wattle were less severe in both MOD and CONV than in CWDB (P<0.0001) and CWODB (P<0.0001 and P=0.01, respectively), and MOD hens continued to have higher scores than birds in CONV (P=0.002).

Values for wounds to the tail/cloaca differed significantly among treatments (P<0.0001), and, unlike other condition measures, improved with age (P<0.0001) (Table 5.3). Age effect was significant for CWODB (P=0.0027) and MOD (P=0.0007). At wk 31, significantly lower scores were observed for hens in CWODB than for birds in CONV (P<0.0001), MOD (P=0.0003) and CWDB (P=0.01). For wk 65, wound scores in the tail/cloaca region were less severe in MOD than in CWDB (P=0.03) and CWODB (P=0.01), and less severe in CONV than in CWODB (P=0.05).

Treatment differences in keel bone condition scores were not significant (P=0.06), however a decrease in scores was observed with age and for all treatments (P<0.0001) (Table 5.3). Scores were comparable between cage housing systems at wk 31, and by 65 wks, only hens in CONV and MOD differed, with CONV hens exhibiting a lower degree of keel bone deformation (P=0.01).

5.4.2 Productivity

5.4.2.1 HD and HH Productivity

Overall, hen-day egg production did not differ among housing systems (P=0.9181) (Table 5.4). An increase in production was observed between wks 20 (80.1%) and 24 (95.4%) (P<0.0001), as well as from wk 28 (94.2%) to wk 32 (96.4%) (P=0.01). Production slowly declined thereafter, decreasing from 95.5% at wk 40 to 91.7% at wk 44 (P=0.0002), and overall, production declined with age (P<0.0001).

Hen housed egg production was also consistent between housing systems (P=0.85) (Table 5.4), and overall, decreased as birds aged (P<0.0001). An increase in hen-housed egg production occurred both between 20 (79.7%) and 24 wks (95.1%) (P<0.0001), and between wks 28 (93.4%) and 32 (95.8%) (P=0.01). As observed for hen-day production, hen-housed performance also gradually declined after wk 32, and decreased significantly between wks 40 (94.9%) and 44 (91.1%) (P=0.0004).

5.4.2.2 Location of Lay

The proportion of eggs laid in the nest box averaged 92.1% in MOD, 92.4% in CWDB and 94.6% in CWODB (Table 5.4), and no differences were observed between treatments for percentage eggs laid in the nest box (P=0.23) or on the floor (P=0.26). Although CWDB hens laid a higher percentage of eggs in the open dustbath than CWODB hens (P<0.0001) who, on occasion, laid their egg while positioned on the edge of the closed dustbath, the percentage of CWDB eggs laid in the dustbath was very low (Table 5.4).

The overall percentage of eggs laid in the nest increased from wk 20 (85.9%) to wk 24 (95.8%) (P=0.005), a difference that was most noticeable for MOD hens who increased their nest use from 72.8% to 91.1% during this time (P<0.0001). Along with increased nest laying that occurred early on, a decrease in the percentage of cage eggs was also observed between wks 20 (12.9%) and 24 (4.2%) (P=0.01) for all treatments. Although the overall percentage of cage and dustbath laid eggs did not change with age (P=0.38 and P=0.99, respectively), for CWDB and CWODB hens, decreases in nest laid eggs were significant over time (P=0.001 and P=0.01, respectively), as were the ensuing increases in cage laid eggs (P=0.001 and P=0.01, respectively).

5.4.2.3 % Cracked Eggs

The percentage of cracked eggs was significantly higher for eggs that were laid in cages with nest sites (P<0.0001) (Table 5.4). Cracked egg percentage was lower in CONV than in CWDB (P<0.0001), CWODB (P<0.0001), and MOD (P<0.0001), however no differences were observed between the systems with nests. Overall (P=0.01), and within each treatment (P<0.0001), the proportion of cracked eggs was found to increase with hen age.

For eggs collected at wks 40 and 44, when manual, cumulative collection and conveyer simulation collection techniques were compared on two consecutive collection days, significantly more eggs from furnished cages were cracked when eggs were collected by the accumulation technique (P=0.0001). In contrast, when eggs were collected as they rolled onto the egg tray, the percentage of cracked eggs did not differ between treatments (P=0.36).

5.4.2.4 % Dirty Eggs

The overall proportion of dirty eggs differed between cage treatments (P<0.0001), with CWDB cages exhibiting higher percentages than CONV (P=<0.0001), MOD (P=<0.0001), or CWODB (P=<0.0001) units (Table 5.4). Age did not influence the percentage of dirty eggs for the combined treatments (P=0.91), CWDB (P=0.19), MOD (P=0.98), or CONV (P=0.36), however a higher than average proportion of dirty eggs in CWODB at 64 wks (5.0%), resulted in a significant age effect for eggs from CWODB (P=0.04).

When eggs were collected using the normal cumulative collection method during wks 40 and 44, no differences in the proportion of dirty eggs was observed between treatments. However, when eggs were collected individually at these ages, the treatment effect was significant (P=0.05). In particular, the percentage of dirty eggs in CWDB (3.82%) was higher than the percentage in CWODB (0.88%) (P=0.01).

5.4.2.5 Egg and Eggshell Quality

Values for specific gravity, egg weight, shell weight, percentage shell and shell thickness are shown in Table 5.4. Differences in specific gravity were not observed between cage treatments (P=0.65). Although age effect was significant, with specific gravity decreasing over time for all treatments (P<0.0001), a cage by age interaction was not observed (P=0.98). Egg weight was not influenced by housing condition (P=0.27) however, as expected, eggs increased in weight over time for all treatments (P<0.0001).

A treatment effect was observed for eggshell weight (P<0.0001). Eggs from CWODB exhibited higher shell weight than eggs from CWDB (P=0.0002), MOD (P<0.0001) and CONV (P<0.0001), and shell weight was also higher for CWDB and CONV hens than for birds in MOD (P=0.003 and P=0.001, respectively). Not surprisingly, as eggs became larger with age, eggshell weight also increased (P<0.0001).

Treatment differences in percentage shell mirrored results for eggshell weight, with an overall treatment effect (P<0.0001), and higher percentage shell for CWODB eggs than eggs from CWDB (P=0.02), MOD (P<0.0001) and CONV (P<0.0001). Percentage shell was also higher for eggs from CWDB than MOD (P<0.0001) and CONV (P=0.04), and was higher in CONV than in MOD (P<0.0001). A decrease in percentage shell was noted with age (P<0.0001).

Shell thickness was also influenced by housing condition (P<0.0001), and differences were observed among all four treatments. CWODB hens produced thicker-shelled eggs than CWDB (P=0.05), MOD (P<0.0001) and CONV (P<0.0001) hens, CWDB shells were thicker than shells from MOD (P<0.0001) and CONV (P=0.002), and eggshells were thicker in CONV than in MOD (P=0.005). The effect of age on shell thickness was also significant (P<0.0001) whereby shell thickness values decreased from wk 20 (0.395 mm) to wk 32 (0.362 mm) (P<0.0001), but increased continuously between wks 32 and 64 (P<0.0001).

5.4.2.6 Feed Consumption

As shown in Table 5.5, FCE differed significantly among cage systems (P<0.0001) and decreased with age for all treatments (P<0.0001). At 28 wks, average feed conversion ratio was significantly lower in MOD cages than in CWDB (P=0.01) and CWODB (P=0.004) but did not differ between CONV and CWDB (P=0.21), CWODB (P=0.10) or MOD (P=0.09), or between CWDB and CWODB (P=0.75).

By 64 wks, average feed conversion ratio was significantly lower in MOD cages than CWDB ($P=0.0002$) and CWODB ($P<0.0001$), and was also lower for CONV than CWDB ($P<0.0001$) and CWODB ($P<0.0001$). No differences were observed between CWDB and CWODB ($P=0.38$), or between CONV and MOD ($P=0.30$).

Overall, feed conversion was more efficient in CONV than in CWDB ($P=0.0004$) and CWODB ($P<0.0001$), and more efficient in MOD than in CWDB ($P=0.0001$) and CWODB ($P<0.0001$). Treatment differences were not observed between CWDB and CWODB ($P=0.46$), or between MOD and CONV ($P=0.69$).

Feed intake also differed significantly among treatments ($P=0.004$) and increased with age for all cage types ($P<0.0001$) (Table 5.5). Although no treatment differences were observed at 26 wks, by 27 and 28 wks MOD hens were consuming less feed than CWDB ($P_{27}=0.04$; $P_{28}=0.03$) and CWODB ($P_{27}=0.04$; $P_{28}=0.03$) hens. By 64 wks, feed consumption was lower for CONV hens than for birds in CWDB ($P=0.002$) and CWODB ($P<0.0001$), and MOD hens continued to consume less feed than CWDB ($P=<0.0001$) and CWODB ($P=<0.0001$) birds. No differences in feed intake were observed between CONV and MOD ($P=0.28$), or between CWDB and CWODB ($P=0.24$).

Overall, MOD hens consumed less feed than CWDB ($P=0.01$) and CWODB ($P= 0.001$) hens. No difference in overall feed consumption was apparent between hens in CWODB and CONV ($P=0.06$), or between CONV and MOD birds ($P=0.07$).

5.4.2.7 Live weight

Average live body weight was lower for CWODB (1.682 ± 0.031) hens than for birds in CONV (1.771 ± 0.012) ($P=0.01$) and MOD (1.773 ± 0.012) ($P=0.01$). No differences in body weight were observed between birds in CONV and MOD ($P=0.92$), or between CWDB (1.713 ± 0.031) and CWODB hens ($P=0.48$). CWDB birds did not weigh less than hens in CONV ($P=0.08$) or MOD ($P=0.08$).

5.4.2.8 Mortality

The total incidence of mortality in this study was 4.1% and, as shown in Table 5.6, ranged from 3.5 to 4.8%. Treatment differences in mortality were not observed (P=0.2247). The primary cause of death for hens in CWODB was cannibalism and one hen in MOD accidentally suffered a broken neck after placing her head underneath the perch. Additional causes of death included bone-related problems such as cage layer fatigue and fractures, as well as internal ovulation.

5.5 Discussion

5.5.1 Plumage Condition

The loss of feather covering diminishes hen well being because it impairs hen thermoregulatory capacity (Leeson and Morrison, 1978) and results in large part from feather pecking activity, which is painful for hens (Gentle and Hunter, 1990). Overall higher total and individual region feather condition scores in CONV and MOD than in colony cages and similar total and individual scores between MOD and CONV suggest that group size was a critical contributing factor to feather condition in this study. It is likely that diminished feather scores in the colony cages were predominantly due to feather pecking activity. In the larger group cages both the potential number of feather peckers and victims was higher than in CONV and MOD, and feather pecking activity and cannibalism were elevated in CWDB and CWODB. Previous studies have also demonstrated that plumage scores decrease with increasing group size (Hughes and Duncan, 1972; Bilčik and Keeling, 1999) and that the majority of feather damage in layer flocks results from severe feather pecking (Vestergaard et al.,1993; Bilčik and Keeling, 1999).

Overall improved total and individual region feather condition observed in CWDB over CWODB further suggests that the presence of a dustbath in large group cages was instrumental in reducing feather damage. Enabling hens to perform natural dustbathing and foraging behaviour may not only have contributed to structural maintenance of feathers (Simmons,1964; Healy and Thomas, 1973; Borchelt and Duncan, 1974) but likely also contributed to reduced feather pecking activity (Abrahamsson and Tauson, 1997) in CWDB. Appleby et al. (2002) also found lower levels of feather damage for hens in cages with a dustbath.

The overall deterioration of plumage condition observed with age is consistent with previous findings (Abrahamsson et al., 1996; Wahlström et al., 2001), and may be related to a progressive development from gentle to severe feather pecking (Huber-Eicher and Sebö, 2001). Friere et al. (1999) also suggest that feather pecking activity in general may increase as the feathers of caged hens become more damaged.

Feather scores for individual body regions provide additional insight as to treatment differences in plumage condition. Feather loss in the head and neck region is most often caused by aggressive pecking (Bilčík and Keeling, 1999), a behaviour associated with frustration (Duncan and Wood-Gush, 1971), and establishing and maintaining dominance (Savory, 1995). In the present study, lower scores in the head and neck region of colony birds, and especially CWODB hens, therefore suggests higher levels of aggressive pecking in large group cages, particularly those without a dustbath. Increased aggressive pecking may have resulted from elevated frustration due to competition for cage resources and the continual need to establish social hierarchies in a cage of 26 hens. Notably, Bilčík and Keeling (1999) showed increased feather damage for pen-housed hens in groups of 30 than hens in groups 15 or 60, suggesting greater instability of social order in the mid-sized groups, and Keeling et al. (2003) also provided evidence of social disruption when hens were housed in groups of 30.

Lower back scores for CWDB and CWODB hens, both at 31 and 65 wks, are consistent with increased feather pecking (Tauson et al., 2006) and trampling activity observed in the colony cages. Trampling was also observed in CONV, where space limitations often required hens to step on top of other birds in order to move about the cage, however the large number of hens in colony cages resulted in a higher incidence of the behaviour in CWDB and CWODB. Feather damage caused by trampling can be exacerbated by claw overgrowth in cage systems (Appleby et al., 1993), and Friere et al.

(1999) suggest that because hens show elevated interest in loose and protruding feathers, pecking is likely to be directed at trampling-damaged feathers. Hens in CWDB and CWODB, may therefore have been more susceptible to feather pecking in the back region than birds in CONV or MOD.

Trampling activity likely also contributed to wing feather loss in CONV and CWODB, where condition scores were poorest at 65 wks. Additional damage to wing feathers in these two systems can be attributed to feather pecking activity, and hen abrasion against cage components or other hens (Tauson, 1984; Bilčik and Keeling, 1999). Although wing condition scores in this study did not differ at 31 wks, similarly low scores in CONV and CWODB by 65 wks suggest that long-term wing feather loss in small group conventional cages was comparable to the level of loss in large group systems lacking a dustbath. Notably, wing condition scores were highest in MOD, where, unlike in CONV, nest box placement on the same side of each consecutive cage created solid sides between neighbouring units, thereby limiting between-cage feather pecking to that occurring at the feeder, and minimizing abrasion against the cage sides. The presence of the two-doored nest box, which aided in improving traffic flow, and a perch, which encouraged 3-dimensional use of the cage space, may also have reduced wing abrasion against the cage floor or other hens in MOD by creating more physical space for movement and rest (Webster and Hurnik, 1990). Wing feather condition of CWDB birds was comparable to MOD scores, suggesting that even in large group cage units, long-term wing feather deterioration can be minimized by providing hens with opportunities to dustbathe and forage, in addition to nesting and perching. Solid sides in CWDB and CWODB may also have contributed to reduced between-cage pecking and cage abrasion, as compared with CONV.

The severity of feather loss in the tail and vent regions of CWODB hens at both 31 and 65 wks is also likely attributable to increased feather pecking in large group cages, particularly those lacking a dustbath (Tauson et al., 2006), as well as due to hen-cage and hen-hen abrasion (Bilčik and Keeling, 1999). Poorer vent feather condition of CWDB hens than CONV or MOD birds at 31 wks but not at 65 wks may be linked to elevated productivity at the younger age. Notably, the incidence of cannibalism, which was highest in colony cages, also peaked during maximum egg production. Hormonal changes associated with the onset of lay have previously been linked to increased incidence of feather pecking (Hughes, 1973; Hughes 1980), and at 31 wks may still have had an effect on the severity of vent feather pecking in cages with large numbers of hens.

It is somewhat surprising that vent feather condition scores were higher in CONV than in all other cage systems at 65 wks. It is possible that crowding in CONV made it difficult for hens to bend, and therefore view and peck at the vent region of cage mates. In contrast, in all other units, when one or more hens entered the nest or dustbath, or stood on the perch, hens remaining in the cage area had additional floor space to move. In addition, hens standing on the cage floor of MOD, CWDB and CWODB would have had an elevated view of the vent region of perched birds, thereby increasing the likelihood of vent pecking in these cages. Lower vent feather scores in MOD than in CONV were not however associated with cannibalistic behaviour, as cannibalism did not occur in MOD.

The presence of a dustbath may have contributed to reduced breast feather loss early on in CWDB. However, given lower scores for both colony units at 65 wks than for CONV and MOD, and higher scores for MOD than CONV at this time, long-term feather condition of the breast region was likely more affected by pecking behaviour and abrasion.

Lower belly condition scores in MOD, CWDB and CWODB than in CONV at both ages may have resulted from increased abrasion in the three furnished systems due to nesting on the artificial turf, dustbathing and perching activity. Furthermore, Bilčík and Keeling (1999) found that the feathers from the belly region, which are easily removed and are readily accessed by peckers when birds are perching, are the first body part to become denuded, suggesting that birds in MOD, CWDB and CWODB may have been more susceptible to feather pecking in the belly region than birds in CONV. This may have contributed in part to cannibalism in colony cages as the skin in the lower abdominal region is relatively thin (Glatz and Lunam, 1996) and wounds from pecking or clawing at the exposed skin might attract additional pecking.

5.5.2 Feet and Claw Condition

Higher foot and claw condition scores in MOD at 65 wks, and comparable values between CONV, CWDB and CWODB confirm previous findings that damage to feet and claws is reduced in furnished systems, but increased in large group environments (Appleby et al., 2002). Improved scores in MOD, which may reflect increased opportunity for perching in furnished cages housing only 3 hens, and consequent reprieve from continual or prolonged standing on a sloping wire floor (Appleby and Hughes, 1990; Duncan et al., 1992), emphasize the welfare and production value of providing adequate perching facilities for hens in cage systems. In addition, low overall foot and claw scores in this study, despite the presence of nesting, perching and dustbathing facilities, further reiterates the importance of providing claw abrasives in cage systems, a stipulation of the European Union laying hen directive (CEC, 1999). The absence of bumblefoot in this study also suggests that the rectangular perch design and wooden material were suitable for Shaver White Leghorns.

5.5.3 Wounds: Comb/Wattle

Condition scores for wounds to the comb/wattle support behavioural observations of increased aggressive pecking in CONV than in MOD (Chapter 2) and indicate that aggression and consequent hen injury can be reduced by incorporating nesting and perching facilities in conventional cages. Reduced values in colony cages are consistent with increased feather loss observed in the head and neck region of CWDB and CWODB hens, and the suggestion that aggressive pecking was highest in the 26-hen cages.

5.5.4 Wounds: Tail/ Vent

Improved tail/vent wound scores with age, and significantly higher feather scores for CWDB than CWODB hens at 31 wks, support the above intimation that feather pecking activity was highest in the vent region during peak production, and that injurious pecking was reduced in colony cages by enabling hens to dustbathe. Scores, which are consistently higher in MOD and CONV than in colony cages, are further reflective of the detrimental effect of group size on feather pecking activity in this study.

5.5.5 Keel Bone Scores

Reduced keel bone scores in furnished cages, particularly MOD, are consistent with previous findings of a higher incidence of keel bone deformation in cages where hens are able to perch (Tauson and Abrahamsson, 1994; Wahlström et al., 2001). Although deformation of the keel is believed to result from the combined effects of osteoporosis and pressure on the sternum during perching (Appleby et al., 1993), it is not certain that keel bone deformation in the present study was detrimental to hen welfare, as structural bone loss was actually reduced in the three furnished systems (Chapter 4; Jendral et al., 2008).

5.5.6 Productivity

Comparable HH and HD results between cage systems indicate that cage housing environment did not impact egg production in this study. Observed production increases between 20 and 24 wks, and between 28 and 32 wks, were likely the result of the full competence of hens reaching sexual maturity and peak production, respectively. The introduction of midnight lighting at wk 32 may also have contributed to increased productivity at the latter age.

High incidence of nest box use in each of the furnished cage systems, and low incidence of floor and dustbath laid eggs reiterates the importance of providing a suitable nesting environment to accommodate both welfare and production, and the advantage of limiting dustbath access to the afternoon period (Appleby et al., 1993; Wall et al., 2002). In contrast to CWDB and CWODB, where the floor of the nest box was continual with the cage floor, an initial adjustment period appears to have occurred in MOD, during which time hens learned to step up and into the nest site. Once access was learned, MOD hens clearly preferred this nesting environment to laying on the cage floor or from the perch, and their high incidence of nest box use continued with age. Decreased nest-laid eggs with age in CWDB and CWODB suggests that in large group cages, continual competition for the nest resource may have deterred hens from attempting to gain access to the nest box over time (Guesdon et al, 2006). Hens may also have been avoiding displacement from the nest site, aggressive pecking and being trampled as they attempted to nest. Such behaviours, which were commonly observed in the colony nest environment, may indicate that in large group cage systems, multiple or larger nest sites would better accommodate synchronous oviposition.

Although the percentage of cracked eggs was higher in cages containing nest sites than in CONV, the absence of treatment differences in cracked eggs when collection was performed using conveyer simulation suggests that cracking in MOD, CWDB and CWODB was largely due to concentration and consequent collision of eggs on the egg tray in front of the nest site (Abrahamsson et al., 1995, Wall et al., 2002). Operating a conveyor system at intermittent intervals during peak egg production, as Wall and Tauson (2002) suggest, may therefore significantly reduce the proportion of cracked eggs in furnished cage systems. Inclusions of egg saver wire or nest curtain devices have also been shown to reduce the proportion of cracks in eggs laid in cages with nest sites (Wall and Tauson, 2002). The minimization of cracked eggs when conveyer simulation collection was used in the present study also suggests that nests in MOD, CWDB and CWODB were well designed to prevent damage caused by eggs being stepped on or pecked at. In addition, the increase in the proportion of cracked eggs with time for all treatments suggests that cracking was influenced by age for all hens, rather than by cage or nest box design.

Despite a low percentage of dustbath laid eggs, the increased proportion of dirty eggs measured in CWDB was likely due to a combination of eggs laid in the dustbath and the use of peat moss as a dustbathing substrate, which readily adhered to moist eggs. Soiling of eggs inside the nest box may have occurred, however MOD and CWODB hens also had access to an artificial turf lined nesting facility, and the proportion of soiled eggs in these systems was comparable to that in CONV. Appleby et al. (2002), who found that dustbath laid eggs were more likely to be dirty, also indicated that soiled eggs were increasingly common in cages with more birds, so perhaps the large number of hens in CWDB further contributed to soiling.

5.5.7 Egg and Eggshell Quality

Neither specific gravity, nor egg weight were influenced by cage treatment, intimating that egg quality was comparable in furnished and CONV cages. Tauson (2003) and Guesdon et al. (2006) also determined that egg weight does not differ between furnished cage designs. In contrast however, increased eggshell weight and thickness, and percentage shell for eggs from colony cages, suggest that caged hens with greater opportunity for movement and load bearing exercise produced thicker-shelled eggs. Since hens in CWDB and CWODB were also better able to prevent structural bone loss (Chapter 4; Jendral et al., 2008), these combined findings indicate that the performance of load-bearing exercise by caged hens increased efficiency of calcium metabolism, an advantage to both hen welfare and productivity. Additionally, since a relationship between shell thickness and shell strength has previously been established (Roberts, 2004), higher shell thickness measures for CWDB and CWODB eggs provides further evidence that cracking observed in eggs from furnished systems was related to egg collisions, and not to reduced eggshell quality.

As expected, for all treatments, measures of specific gravity and percentage shell decreased with age as eggs increased in size. The unexpected increase in shell thickness from wk 36 onwards for all treatments may be attributed in part to the top dressing of feed with oyster shells from wk 32 to the end of the trial. Additional night lighting beginning at wk 32, and consequent opportunity for feed intake and access to a readily available source of calcium close to the period of eggshell formation, may have further contributed to increased eggshell thickness observed beyond wk 36.

5.5.8 Feed Consumption, Live weight and Mortality

Higher feed intake and lower feed conversion efficiency in colony cages indicates that feed energy requirements were highest for hens in cages where insulative feather cover was also lowest. Tauson (2006) suggests that feather loss in the back and breast regions leads to increased energy demands as a result of severe heat loss, and indeed, CWDB and CWODB hens in the current study had the lowest condition scores for both of these regions. Higher energy demands may have been further necessitated by increased opportunity for movement in colony cages, as well as in MOD. In MOD however, higher breast feather scores likely contributed to improved insulative cover which may have offset additional activity-related energy use, such that feed intake and efficiency values in MOD were comparable to those in CONV.

Hens in CWODB demonstrated lower live weights than birds in either CONV or MOD. This likely resulted from the reduced contribution of feather weight to overall body mass, and from the diversion of feed energy to heat loss and increased activity requirements, rather than to body condition. Similar findings have previously been reported for hens housed in aviary systems, where the amount of physical activity performed by hens is considerably elevated (Taylor and Hurnik, 1994). Stress has also been linked to lower body weight (Siegel, 1995), and it is likely that hens in groups of 26 experienced greater stress than in groups of 3, even in cage environments such as CWODB where the expression of innate behaviours was encouraged by cage furnishings. This is further supported by poorer feather cover observed in colony hens, and findings that feather-damaged birds show increased fear response when presented with novel stimuli (Ouart and Adams, 1982). Similar body weights observed between CWDB hens and birds in MOD and CONV provides additional evidence that access to a dustbathing facility contributed to reduced stress in CWDB hens.

The overall incidence of mortality was low, and consistent with previous levels observed in conventional and furnished cage studies of beak-trimmed hens (Appleby et al., 2002; Guesdon et al., 2006). Although causes of mortality were diverse, cannibalism was particularly problematic in CWODB, especially during peak production. These findings further reflect the importance of including amenities, such as a dustbath, that reduce pecking activity in large group cage systems, where feather pecking and cannibalistic behaviour are likely to spread rapidly and affect many hens (Weitzenburger et al., 2005).

5.5.9 Summary and Conclusions

To summarize, an overall evaluation of hen condition and production in this study reveals that total and regional feather loss was increased in large group colony cages but improved in CWDB over CWODB. Wing and breast feather condition was superior in MOD systems than in CONV, and wounds to the head and tail were reduced in small group, modified cages. Feather and aggressive pecking activity were therefore likely more severe in large group cages, but reduced in modified systems, and by allowing hens in large group cages to access a dustbathing facility. Foot condition was also improved through perching in MOD. Egg productivity was not influenced by cage environment, however hens clearly preferred to oviposit in the nest boxes provided, and dustbath laying was minimized through use of a timed closing mechanism. The higher percentage of cracked eggs in furnished systems likely resulted from collisions in the egg tray in front of the nest box, however cracking was reduced when conveyor simulation collection was introduced. A combination of dustbath laid eggs and use of peat moss as a dustbathing substrate may have contributed to the increased proportion of dirty eggs observed in CWDB, however eggshell quality was improved in colony systems, which may be linked to superior efficiency of calcium metabolism for birds with increased opportunity for load bearing exercise. Higher feed energy requirements and lower body weights for colony hens than for birds in MOD or CONV were likely due to reduced feather cover and resultant increased heat loss and stress for birds in cages with 26 hens, however increased activity in furnished cages may have also have contributed to elevated energy demands. Finally, although mortality did not differ between cage treatments, reduced feather cover in the absence of a dustbath may have increased the incidence of cannibalism-related deaths in CWODB.

The findings from this study provide evidence that the welfare of caged Shaver White Leghorns was reduced by housing birds in groups of 26 hens, but that parameters of hen productivity and welfare were improved by inclusion of nesting and perching facilities in MOD, CWDB and CWODB, and by inclusion of a dustbath in large group colony cages. Further studies should continue to examine improvements to and the welfare and production benefits of cage amenities, as well as strain options and optimal group sizes for housing laying hens in furnished cage systems.

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5.7 Tables

Table 5.1 Scoring method used to assess hen plumage, foot and claw condition.

Score	Feathers	Feet	Claw
4	Well feathered; few or no worn or deformed feathers	Good condition of foot pads, digits, claw folds; no lesions	Claws of short or normal (pullet) length; no deformation
3	Feathers deteriorated but complete coverage	Lesions clearly visible but few in number and only of minor concern	Claw growth beyond short or normal length
2	Feather condition clearly deteriorated, and/or with naked areas	Severe lesions on several areas of the foot	Claws clearly overgrown but not twisted
1	Severely damaged plumage; no or very small areas having feather cover	Very poor foot condition with inflamed and/or bleeding fissures	Extremely overgrown claws; often twisted

Table 5.2 Average feather condition scores for total body and individual body regions of hens housed in conventional, modified and colony cage systems at 31 and 65 wks.

	CONV (90)[1]		MOD (90)[1]		CWDB (312)[1]		CWODB (312)[1]	
31 Wks								
Region	LSM	SEM	LSM	SEM	LSM	SEM	LSM	SEM
Total Body	23.63^{a}	0.45	22.99^{ab}	0.45	21.27^{bc}	0.72	19.14^{c}	0.72
Neck	3.76^{a}	0.09	3.76^{a}	0.09	2.82^{b}	0.14	2.79^{b}	0.14
Back	3.88^{a}	0.09	3.78^{a}	0.09	3.27^{b}	0.14	3.00^{b}	0.14
Wings	2.93	0.07	3.01	0.07	3.13	0.10	3.03	0.10
Tail	2.73^{a}	0.07	2.78^{a}	0.07	2.70^{ab}	0.10	2.44^{b}	0.10
Vent	3.50^{a}	0.09	3.43^{a}	0.09	3.00^{b}	0.14	2.18^{c}	0.14
Breast	3.71^{a}	0.09	3.71^{a}	0.09	3.48^{ab}	0.14	3.12^{b}	0.14
Belly	3.52^{a}	0.09	3.22^{b}	0.09	2.88^{c}	0.14	2.58^{c}	0.14
65 Wks								
Total Body	14.39^{a}	0.46	15.06^{a}	0.45	12.94^{b}	0.72	11.17^{c}	0.72
Neck	2.52^{a}	0.09	2.66^{a}	0.09	2.36^{ab}	0.14	2.06^{b}	0.14
Back	2.43^{a}	0.09	2.53^{a}	0.09	1.94^{b}	0.14	1.65^{b}	0.14
Wings	1.80^{c}	0.07	2.33^{a}	0.07	2.16^{ab}	0.10	1.92^{bc}	0.10
Tail	1.26^{ab}	0.07	1.39^{a}	0.07	1.40^{ab}	0.10	1.17^{b}	0.10
Vent	1.90^{a}	0.09	1.32^{b}	0.09	1.38^{b}	0.14	1.14^{b}	0.14
Breast	2.09^{b}	0.09	2.38^{a}	0.09	1.90^{c}	0.14	1.63^{c}	0.14
Belly	2.76^{a}	0.09	2.44^{b}	0.09	1.81^{c}	0.14	1.61^{c}	0.14

[a-c] Means within the same row and body region lacking a common superscript differ significantly ($P<0.05$).

[1] Number of hens assessed. CONV = conventional cage; MOD = modified cage; CWDB = furnished colony cage with dustbath; CWODB = furnished colony cage without dustbath.

Table 5.3 Average feet and claw, and keel bone condition scores, and wound scores to the comb/wattle and tail/cloaca of hens housed in conventional, modified and colony cage systems at 31 and 65 wks.

	CONV (90)[1]		MOD (90)[1]		CWDB (312)[1]		CWODB (312)[1]	
31 Wks								
	LSM	SEM	LSM	SEM	LSM	SEM	LSM	SEM
Feet	3.00	0.05	3.08	0.05	2.88	0.08	2.90	0.08
Claw	2.99	0.05	3.07	0.05	2.97	0.08	2.97	0.08
Keel	3.69	0.08	3.50	0.08	3.62	0.12	3.62	0.12
Comb/Wattle	3.63^{b}	0.05	3.87^{a}	0.05	3.68^{ab}	0.08	3.79^{ab}	0.08
Tail/Cloaca	3.52^{a}	0.06	3.48^{a}	0.06	3.42^{a}	0.09	3.09^{b}	0.09
65 Wks								
Feet	2.85^{b}	0.05	3.03^{a}	0.05	2.74^{b}	0.08	2.83^{ab}	0.08
Claw	1.96^{b}	0.05	2.15^{a}	0.05	1.92^{b}	0.08	2.01^{ab}	0.08
Keel	2.99^{a}	0.08	2.72^{b}	0.08	2.73^{ab}	0.12	2.74^{ab}	0.12
Comb/Wattle	3.56^{b}	0.05	3.79^{a}	0.05	3.16^{c}	0.08	3.31^{c}	0.08
Tail/Cloaca	3.67^{ab}	0.06	3.75^{a}	0.06	3.51^{bc}	0.09	3.45^{c}	0.09

$^{a\text{-}c}$Means within the same row and body region lacking a common superscript differ significantly ($P<0.05$).

[1] Number of hens assessed. CONV = conventional cage; MOD = modified cage; CWDB = furnished colony cage with dustbath; CWODB = furnished colony cage without dustbath.

Table 5.4 Productivity of CONV, MOD, CWDB and CWODB hens between 20 and 64 wks.

	CONV		MOD		CWDB		CWODB		Treatment
	LSM	SEM	LSM	SEM	LSM	SEM	LSM	SEM	P Value
HD Productivity (%)	91.0	1.7	90.6	1.3	90.8	1.4	90.9	1.4	0.92
HH Productivity (%)	90.9	1.7	90.4	1.3	90.1	1.4	90.2	1.4	0.83
% Laid in NB	-	-	92.1	0	92.4	0	94.6	0	0.23
% Laid in DB	-	-	-	-	1.8^{a}	0	0^{b}	0	<0.0001
% Laid in Cage	100	0	7.8	0	5.8	0	5.4	0	0.26
% Cracked Eggs	5.3^{a}	0.8	13.2^{b}	1.3	16.1^{b}	1.5	15.4^{b}	1.6	<0.0001
%Dirty Eggs	2.4^{a}	0.3	2.2^{a}	0.1	4.9^{b}	0.4	2.3^{a}	0.3	<0.0001
Specific Gravity	1.081	0	1.081	0	1.082	0	1.082	0	0.65
Egg Weight (g)	57.8	0.2	57.8	0.2	57.5	0.2	57.9	0.2	0.27
Shell Weight (g)	5.5^{b}	0	5.4^{c}	0	5.5^{b}	0	5.6^{a}	0	<0.0001
Percentage Shell	9.51^{c}	0.03	9.38^{d}	0.03	9.58^{b}	0.04	9.72^{a}	0.04	<0.0001
Shell Thickness (mm)	0.374^{c}	0.001	0.372^{d}	0.001	0.379^{b}	0.002	0.382^{a}	0.002	<0.0001

$^{a\text{-}d}$Means within the same row and body region lacking a common superscript differ significantly ($P<0.05$). CONV = conventional cage; MOD = modified cage; CWDB = furnished colony cage with dustbath; CWODB = furnished colony cage without dustbath.

Table 5.5 Average feed conversion efficiency (kg feed/ kg egg) (±SEM) at 28 and 64 wks and average feed consumption (g / hen / day) (±SEM) at 26, 27, 28 and 64 wks for hens in CONV, MOD, CWDB and CWODB.

FCE (kg feed / kg eggs)				
Age	CONV	MOD	CWDB	CWODB
28	1.84^{ab} (0.03)	1.77^{a} (0.03)	1.91^{b} (0.05)	1.92^{b} (0.05)
64	2.06^{a} (0.03)	2.11^{a} (0.03)	2.37^{b} (0.05)	2.45^{b} (0.05)
TRT Avg	1.95^{a} (0.03)	1.94^{a} (0.03)	2.14^{b} (0.04)	2.19^{b} (0.04)
Food Intake (g/hen/day)				
Age	CONV	MOD	CWDB	CWODB
26	99.00 (1.44)	95.81 (1.44)	97.06 (2.28)	97.77 (2.28)
27	92.94^{ab} (1.44)	89.53^{a} (1.44)	94.99^{b} (2.28)	95.01^{b} (2.28)
28	96.86^{ab} (1.44)	93.87^{a}(1.44)	99.73^{b} (2.28)	99.94^{b} (2.28)
64	118.38^{a} (1.46)	116.18^{a} (1.44)	126.95^{b} (2.28)	130.71^{b} (2.28)
Trt Avg	101.79^{ab} (1.14)	98.85^{a} (1.14)	104.68^{b} (1.80)	105.86^{b} (1.80)

$^{a-b}$Means within the same row and body region lacking a common superscript differ significantly ($P<0.05$).
CONV = conventional cage; MOD = modified cage; CWDB = furnished colony cage with dustbath;
CWODB = furnished colony cage without dustbath.

Table 5.6 Total mortality and primary causes of mortality in CONV, MOD, CWDB and CWODB cages.

	CONV	MOD	CWDB	CWODB
Total # of Hens	252	252	312	312
# Hens Dead or Culled	9	12	11	14
Mortality, % of HH	3.6	4.8	3.5	4.8
# Hens per Cage	3	3	26	26
Causes of Mortality - % of dead hens				
Cannibalism	11 (1)[1]	-	9 (1)	53 (8)
Cage Layer Fatigue	33 (3)	17 (2)	18 (2)	13 (2)
Broken Bone	22 (2)	17 (2)	18 (2)	13 (2)
Internal Ovulation	33 (3)	8 (1)	9 (1)	-
Septicemia	-	-	9 (1)	-
Renal Failure	-	-	9 (1)	-
Ovarian Tumor	-	8 (1)	-	-
Hepatic Tumor	-	8 (1)	-	-
Prolapsed Uterus	-	8 (1)	9 (1)	-
Other/Unknown	-	25 (3)	18 (2)	20 (3)
Accidents	-	8 (1)	-	-
Causes of Mortality - % of HH				
Cannibalism	0.4	-	0.3	2.6
Cage Layer Fatigue	1.2	1.2	0.6	0.6
Broken Bone	0.8	0.8	0.6	0.6
Internal Ovulation	1.2	0.4	0.3	-
Septicemia	-	-	0.3	-
Renal Failure	-	-	0.3	-
Ovarian Tumor	-	0.4	-	-
Hepatic Tumor	-	0.4	-	-
Prolapsed Uterus	-	0.4	0.3	-
Other/Unknown	-	1.2	0.6	0.9
Accidents	-	0.4	-	-

[1] Number of hens (n) given in parentheses.

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Chapter 6

Alternative Laying Hen Housing Systems in Europe

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6.1 Summary

Alternative housing systems for laying hens are designed to balance the health and welfare of the hen, with the needs and well being of the producer, the consumer, the industry and the environment. Systems are typically evaluated on their ability to provide adequate space for movement and exercise, an environment that allows hens to express natural behaviours, and a setting where aggressive interactions are minimized. Simultaneously however, issues such as productivity, labour requirements, air quality, hygiene, hen and worker health, and system costs must also be adequately addressed. Not surprisingly, a system capable of completely satisfying all of these needs has yet to emerge. However, a number of systems that have attempted to maximize the advantages offered by alternative housing, while minimizing adverse consequences, have been developed and successfully implemented in Europe, and improvements to these systems are ongoing.

European consumers adopt a progressive and proactive approach towards animal welfare and food safety, and by demanding specific products, have a considerable impact on the type of housing systems implemented by producers. Regional welfare directives and legislative policies, which are also influenced by public opinion, may further determine which housing systems are permissible and will provide acceptable welfare and production results under the conditions stipulated. The availability of different alternative housing systems provides producers with flexibility when choosing the system

that best balances their overall goals and needs, with market demand and legislative requirements. The European initiative to adopt more welfare-conducive layer hen housing systems may ultimately impact layer housing practices worldwide, and an evaluation of the European experience is essential to facilitate this transition.

This document provides an overview of alternative laying hen housing systems in Europe, with particular emphasis on developments in the Netherlands, Switzerland and Sweden. Recent changes to laying hen housing legislation in Germany, and the consequences of these changes for the German egg industry are also addressed. By examining the individual markets, circumstances that led to a shift from conventional laying hen cage housing to alternative systems, challenges faced and successes experienced, insight is gained as to the steps that can be taken to guide Canadian producers in the transition to alternative layer housing systems. Many of the principles outlined in this document are also applicable when adopting changes intended to improve the welfare of all agricultural species.

The European Union (EU) was originally founded in 1950, to initiate an integration of democratic European countries and develop a stable and prosperous international market. Member states are required to adhere to the fundamental laws of the EU. To implement minimum EU directives, each member country passes national legislation. The EU has also introduced a Common Agricultural Policy and direct support programs for EU members to ensure quality and safety of food products, guarantee farm incomes, protect the environment and sustainable production, and ensure compliance with animal welfare standards.

In 1986, the EU commission proposed its first set of standards (86/113/EEC) for the keeping of hens in battery cages. These were revised in 1988 (88/166/EEC) to provide more specific guidelines regarding space allowances in battery housing, provisions for eating and drinking, and cage shape and design. However, EU Scientific Veterinary Committee (SVC) evaluations of hen welfare in battery cage systems were unsatisfactory, and a debate ensued within the European parliament concerning a ban of the battery cage. Discussions were fuelled by pressure from the public and animal welfare organizations. While the SVC was also critical of many aspects of alternative housing systems, the committee ultimately concluded that the welfare of the laying hen was inadequately served in conventional cage systems. In 1999, 13 of the then 15 member countries approved a new directive (1999/74/EC) that would prohibit investment in new conventional systems after 2003, and ban their use after 2012. All cage systems would be required to provide nest sites, perches, litter facilities and claw shortening devices, and to increase cage area to 750 cm^2 space per hen. Specifications regarding space requirements and maximum stocking densities were also provided for non-cage alternative housing systems. In 2002, the Commission adopted a trace system for EU egg production units, requiring producer registration, and labeling of eggs with a distinguishable country code, trace number and a farming method code. Organic production is represented by the number 0, free range systems by the number 1, barn rearing by the number 2, and all cage system eggs are labeled with the number 3. The EU has also formulated directives to control food borne zoonoses such as Salmonella. Regulation (EC) No 2160/2003 concerns the control of salmonella and other specified food-borne zoonotic agents and stipulates minimum sampling requirements for agricultural species and food sources. The EU also contributes funding for national compensation programs. Today the EU is comprised of 27 member states, all of which are required to implement the minimum directives stipulated by EU legislation.

The Netherlands was one the original 6 countries to join the EU in 1950. In spite of its extremely small land base and high population density, this member state is the largest net contributor to the EU, and is among the world's top agricultural exporters. The Netherlands leads Europe in proactive policies that strive for sustainable agriculture and environmental protection, and this progressive approach is also apparent in the Dutch concern for animal welfare. Even prior to implementation of the EU directive (1999/74/EC), the Dutch government encouraged producers to convert conventional battery cage systems to alternatives such as deep litter and aviaries. To further encourage the transition to alternative systems prior to the 2012 deadline, as well as to enable producers to adjust to new management strategies required in aviaries, litter or on range, the government initially also planned to offer a 10-year grace period from the proposed 2007 national beak-trimming ban, for those producers who changed systems prior to 2007. The ban on beak trimming however, has since been postponed. Government incentive programs are also being developed to promote organic farming. Consumer demand and pressure from societal groups have also encouraged supermarkets to prohibit the sale of eggs obtained from caged hens.

As a member of the EU, the Netherlands follows the housing requirements and the labeling code stipulated by the EU directive. NL represents the country code. Since enriched cage eggs are sold as category 3 eggs and do not command a higher price, few producers in the Netherlands choose to house hens in enriched cage systems. Of the 30 million laying hens housed, more than 50% are now kept in aviaries, on free range or as organic production, and aviaries comprise the majority of alternative systems. Covered outdoor access areas known as wintergardens are also becoming increasingly popular, and are often combined with barn systems. The Netherlands has developed and revised action plans for controlling Salmonella that include compulsory monitoring, hygiene maintenance and measures required for positive test results. To minimize costs incurred when flocks test positive, more than 80% of producers vaccinate against Salmonella.

Switzerland is a highly industrialized nation, known for its production efficiency and quality, and strong work ethic. Having a very small but mountainous land area, the country depends heavily on foreign trade. Switzerland has chosen to maintain neutrality, but is involved in many international organizations. Citizens are highly educated, well informed, and adopt a progressive and proactive approach towards animal welfare, environmental issues, and international policies. Swiss voters have had a significant impact on animal welfare legislation. In 1969, the Swiss Animal Welfare Act was approved by 85% of voters in the cantonal of Zurich. The Act was the first to include the appropriate keeping of animals as a measure of protection from cruelty. Public pressure to enforce a national Act continued and in 1978, the Swiss parliament approved the Swiss Federal Act on Animal Protection. The federal Act stipulated guidelines for preventing pain and suffering, and described the proper keeping of animals, including freedom for movement, unlawful keeping and allowable housing systems. Authorization of housing systems for animal keeping was now required. In 1981, the Swiss Animal Welfare Ordinance was introduced to establish clear, measurable guidelines for the federal Act. For laying hens, the Ordinance stipulated a minimum requirement of 800 square cm floor area per bird as well as protected nest areas, perches or grating. Under these minimum conditions, conventional battery cages were effectively banned. Although furnished cage systems that could meet these requirements would be permitted if authorized, no such systems were, or have since been approved. Consequently, non-cage systems have prevailed in Switzerland.

Switzerland's laying hen population approximates 3 million birds and table egg production is approximately 75% self-sufficient. Aviaries are the most common housing system and are frequently combined with wintergardens. The Swiss government is currently providing financial incentive for producers to build wintergardens, as well as additional funding if pasture areas are added for free ranging. Consequently over 80% of Swiss layer flocks now have access to outdoor range.

The Authorization Procedure for housing of agricultural species is carried out by the Swiss FVO and for laying hens occurs at the Centre for Housing – Poultry and Rabbits. Systems are evaluated based on their compliance with the AWO and cited literature, and if necessary, physiological and behavioural measures are conducted. If, after testing at the FVO, a system is found to provide appropriate living conditions, the centre may grant pre-authorization for testing in a commercial setting. Systems are tested with 4 flock rotations and each flock is assessed for condition, behaviour, hygiene, manageability, environmental quality and post mortem examinations. Swiss law also permits beak clipping of chicks insofar as the procedure does not interfere with normal feeding.

Switzerland follows a similar labeling format as the EU egg code. While 0 also represents organic production, 1 identifies systems that use free range in addition to outdoor access, 2 refers to floor systems, and 3 implies that eggs are imported, since cage eggs are not produced in Switzerland. Date of lay and producer identification number are optional additions, however the country code (CH) must be present. For imported eggs, cartons must inform consumers that eggs were produced in cages that are not admissible by Swiss standards.

The Swiss Salmonella control policy involves intense monitoring of imported animals, as well as mandatory and voluntary surveillance of animals, housing and supplies, throughout the production period. Producers who market their products directly must finance testing costs independently. The Swiss Egg Industry has conducted a vigorous campaign to promote the quality of the Swiss egg, guaranteeing that hens are housed in welfare friendly systems. Major Swiss corporations have also discontinued purchase of eggs from producers who do not comply with Swiss standards of production.

Sweden is the third largest country in Europe. It is known for efficient production that promotes ecological, economical and sustainable agricultural development. Sweden has embraced organic production and by adopting policies such as certifying products, organizing problem-solving sectors, engaging large food corporations, and establishing good relations with conventional producers has increased consumer awareness, gained consumer trust and encouraged this market to flourish. Swedish consumers are well informed and concerned about environmental issues, food safety and animal welfare, and Sweden's legislative policies reflect this concern. In 1988, the Swedish AWA was altered to prohibit the practice of beak trimming, to require all cage systems to provide a perch and claw abrasive device by 1994, and to ban all cage systems by 1999. Compulsory testing of all new housing systems would be required and certified, provided animal or worker health was not compromised, and beak trimming or medication would not have to be introduced. Compulsory evaluation would be carried out by the Swedish Animal Welfare Agency. Permissible systems would be assessed in a commercial setting for their effect on bird behaviour and condition, use of nest, perch and litter facilities, and environmental conditions. Sweden became a member of the EU in 1995.

In 1997 approximately 80% of Swedish layer hens were still being housed in conventional cages and it had become apparent that a system capable of meeting all of the requirements of the Ordinance was not yet available. A vote to change the wording of the Ordinance, to include cage housing that would provide hens with nest, perch and litter facilities, was held in 1998 and supported by 80% of the parliamentary majority. To maintain compliance with the EU laying hen directive (1999/74/EC), perch space requirements in enriched cages also had to be increased from 12 to 15 cm per bird. Sweden enforces a Salmonella control program that exceeds EU requirements and this has served to limit imports of less expensive eggs from sources where hens are housed in conventional cage systems. The program, which combines mandatory and voluntary testing procedures, receives financial support from the EU and the Swedish government, and has reduced the prevalence of Salmonella to less than 1% in Sweden.

The first enriched, small group cage model passed compulsory testing and was accepted for field trials in 1998. It was approved for commercial use in 2000 and Sweden became the first country to adopt furnished cage systems for commercial production. Today approximately 40% of Sweden's laying hens are housed in furnished cages. Over 50% of egg production occurs in aviaries and deep litter systems. For Sweden, where beak trimming is prohibited and feather pecking and cannibalism have been problematic, the furnished cage has provided an alternative housing solution to non-cage systems. Continued research and development of cage systems has ensured that production in enriched cages is comparable to conventional cage systems.

Germany is Europe's most populous nation and is an original member of the EU. Centrally located amongst industrialized countries, Germany has been forced to devote considerable effort to environmental concerns, which has also increased consumer awareness and involvement in related issues such as animal husbandry. In 2002, the German Animal Welfare Farm Animal Husbandry Ordinance was amended to prohibit the keeping of laying hens in cage systems beyond 2007. Although 90% of consumers were opposed to battery cage housing of laying hens, the German egg industry feared a complete ban of cage systems would have dire consequences for German egg production, since foreign eggs from cage systems would continue to be available for purchase in Germany. The Federal Ministry of Consumer Protection, Food and Agriculture (FAL) has proposed allowance of a small aviary system, as a potential compromise to the new Ordinance. This "Kleinvoliere" is based upon the structure and principles of the original Get-Away cage and its use will be mandatory as of 2009.

As Europeans have gained experience with alternative housing systems, a number of beneficial management strategies have become apparent. Producers and researchers in the Netherlands, Switzerland and Sweden agree that the conditions of the rearing period must resemble those of the production period insofar as possible. This familiarizes birds with their system early on, eases the transition from one system to another, and encourages development and expression of natural behaviours and habits that will improve production. Operators also agree that for non-cage systems where large numbers of birds are housed together, barns must be divided into functional areas that can be accessed by traffic trails. This encourages bird distribution throughout the barn, permits use of amenities without disturbance from other birds, provides safe, quiet places for birds to rest, and helps the producer to observe and manage the system.

A number of strategies can be adopted to improve nest box use and reduce the incidence of floor eggs. For example, by collecting floor eggs often and placing these and system eggs in nest boxes, birds are encouraged to lay in nest sites. Water and feed systems should also be located near the nests so that birds are not drawn away to eat or drink, and adequate lighting should be provided, particularly for lower level nest sites. Additional lighting and electric fencing can also be used to deter birds from laying in problematic, non-nest areas, however use of electric fencing is prohibited in some countries.

Air quality issues are of considerable concern in alternative systems and can be improved by avoiding feeding and watering in the litter area. Litter depth should also be minimized to facilitate drying. Spreading substrates on the floor encourages birds to scratch and dust bath, which serves to rotate the litter and further promote drying. Manure removal and litter renewal should be carried out frequently. For non-cage systems, birds should be encouraged to move upwards and into the housing system where manure will fall onto belts. Staggering of tiers, minimizing distance between systems, incorporating feed and water facilities at different levels and designating top levels for resting further encourages natural vertical tendencies.

Productivity can also be improved in alternative systems by adopting management strategies. Frequent feeding and equal distribution of feed throughout the barn discourages aggression and promotes flock uniformity. Increasing litter appeal by spreading substrate, and preoccupying birds with straw and limestone blocks will redirect pecking, thereby minimizing feather pecking and cannibalism. The additional movement in non-cage systems also promotes bird health. Outdoor systems must be appealing and provide protective cover, to encourage birds to explore. Range areas should be rotated to allow pasture recovery and to accommodate weather conditions, and installation of predator fencing will reduce mortalities.

Choosing a strain of bird that is well suited to a housing system is necessary to compliment the management strategies adopted. Calm, non-aggressive strains are a good choice for non-cage systems where many birds are housed together. Some strains that are less inclined to explore might be better suited to single tiered, floor litter systems or enriched cages. Hybrids with a medium body condition and good plumage are well suited to outdoor range systems.

There is little question that alternative housing systems require considerable management effort, however high productivity, low mortality, and a safe working environment are all achievable, and management skills will continue to develop as experience is gained. While the transition to alternative housing systems may be challenging, the satisfaction of achieving a balance between hen welfare and successful production can be extremely rewarding.

Ongoing research is necessary to continue to improve alternative systems. An increased understanding of hen behaviour and preference will result in improvements to system design and layout, which will enhance use of facilities and impact production efficiency. Genetic research may serve to provide a suitable layer strain that is calm, not aggressive or inclined to feather peck, and produces well. Developments to free range and outdoor systems will enhance hen welfare while ensuring food safety. Finding the appropriate alternative system will require time and practice but will ultimately better integrate the needs of the hen, the producer, the industry and the environment.

6.2 Introduction to the European Union

The European Union (EU) was originally founded in 1950 to initiate integration of democratic European countries and to develop a stable and prosperous international market. EU institutions include the European Parliament, whose members are elected by constituents of the representative country, the Council of the EU, which represents national governments, the European Commission, the motivating and executive force, and the Courts of Justice and Auditors, which ensure compliance with the law and management of EU finances, respectively (Europa, 2005a). Each member state holds presidency of the council for a 6-month period (Appleby, 2003).

The EU was initially comprised of six founding countries including Belgium, Germany, France, Italy, Luxembourg and the Netherlands. Denmark, Ireland and the United Kingdom became members in 1973 and Greece joined the EU in 1981. In 1986, Spain and Portugal also became members, followed by Austria, Finland and Sweden in 1995. Ten additional countries, including Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia joined the EU in 2004 (Europa, 2005a). Bulgaria and Romania are acceding nations and will become official members in 2007. Turkey, Croatia, the Republic of Macedonia and the Ukraine have submitted applications but have yet to begin negotiations for EU membership (Wikipedia, 2005).

All member states are required to adhere to the fundamental laws of the EU, which are based upon treaties that have been approved by all EU member states. Conflicting national legislation is overruled by EU policies (Appleby, 2003; Europa, 2005a). To implement minimum EU directives, each member country passes national legislation (Appleby, 2003).

The EU has also introduced a Common Agricultural Policy and direct support programs for EU members, to ensure quality and safety of reasonably priced food products, guarantee fair farm incomes, protect the environment and sustainable production, and ensure compliance with animal welfare standards (CAP, 2005; SJV, 2005). To achieve these goals, the EU has created a common market in which taxes, import levies and subsidies are not applicable between member states. In this free market, taxation of goods from non-EU nations increases pricing of foreign products, while EU export subsidies are available to equilibrate EU market and world market prices (Sweden, 2004). The EU also promotes its community markets to encourage consumption of EU-produced goods, and has introduced an agricultural fund to provide common financing within the EU (Sweden, 2004).

The CAP was founded 50 years ago to subsidize production of foodstuffs and promote self-sufficient production. Today, the policy emphasizes producer direct payments to encourage quality production and preservation of biodiversity and landscapes, and to support rural economies. Simultaneously, consumers are able to purchase safe food at a reasonable price. Eligibility for direct payments requires compliance with regulations regarding the environment, animal welfare, hygiene standards and sustainable production (CAP, 2005).

6.2.1 Implementation of the EU Laying Hen Directive 1999/74/EC9

Increasing concern for the welfare of farmed animals in Europe prompted the Council of Europe to introduce the Convention on the Protection of Animals Kept for Farming Purposes in 1976. Since the recommendations of the convention were very general, the Council organized a standing committee to outline specific guidelines for animal production (Appleby, 2003). The first opposition to battery cage housing of laying hens occurred in Germany, when a high court ruled that keeping of hens in battery systems was contradictory to German animal welfare legislation (Wilkins, 2004). The issue was presented to the European Commission and in 1986, the commission proposed its first set of standards (86/113/EEC) for the keeping of hens in battery cages. These were revised in 1988 (88/166/EEC) to provide more specific guidelines regarding space allowances in battery housing, provisions for eating and drinking, and cage shape and design (Appleby, 2003; Europa, 2005b). According to the revised directive, all new cage systems would be required to provide 450 cm^2 floor space and at least 10 cm feed trough length per hen, 2 nipple drinkers or cups per cage, a cage height of at least 40 cm over 65% of the cage, and floor slope could not exceed 14% or 8 degrees. By 1995, these standards would be required for all battery cages (Appleby, 2003; Wilkins, 2004; Europa, 2005b). All member states were obliged to implement national legislation to enforce these guidelines (Appleby, 2003).

In accordance with the 1986 Directive, in 1992, the EU Scientific Veterinary Committee (SVC) prepared a report evaluating the welfare of laying hens in battery cages. The SVC evaluations were highly critical of cage systems, and the European Commission prepared a draft for a new directive, recommending that hens be provided with a minimum of 800 cm^2 floor space. However, no changes were implemented (Appleby, 2003; Wilkins, 2004).

In 1995, the European Commission requested a revised evaluation of the welfare of hens housed in battery cages, as well as alternative housing systems. The report remained critical of battery cage systems, and also outlined the welfare advantages and disadvantages of alternative systems (Appleby, 2003; Wilkins, 2004; Europa, 2005b). In particular, the committee noted that hens had strong preferences for laying their eggs in nests, pecking, scratching and dust bathing in litter, and perching. Risks of osteoporosis, and feather pecking cannibalism in conventional cages were also noted (Wilkins, 2004).

A proposal for a new directive was presented by the European Commission in 1998. Since enriched cage systems had recently been introduced for commercial egg production in Sweden, the directive stipulated that hens should be provided with nest boxes and litter facilities. The use of battery cages would be permitted if hens were provided with 800 cm^2 of cage area and cages were at least 50 cm high (Appleby, 2003; Wilkins, 2004). In January 1999, an amended version of the directive was proposed in which battery cages, but not enriched cages would be prohibited (Appleby, 2003). A debate ensued within the European parliament, and discussions were fuelled by pressure from the public and animal welfare organizations. While the 1995 SVC report had been critical of many aspects of alternative housing systems, the committee ultimately concluded that the welfare of the laying hen was inadequately served in conventional cage systems (Wilkins, 2004). On June 15, 1999 13 of the then 15 member countries approved a new directive (1999/74/EC) and after several amendments, the directive was finalized to prohibit investment in new conventional systems after 2003, and ban their use after 2012 (Wilkins, 2004).

In 2002, the Commission adopted a trace system for EU egg production units, requiring producer registration, and labeling of eggs with a distinguishable country code, trace number and a farming method code (Directive 2002/4/EC). Organic production is represented by the number 0, free range systems by the number 1, barn rearing by the number 2, and all cage system eggs are labeled with the number 3 (Europa, 2005b).

6.2.2 The EU Laying Hen Directive 1999/74/EC9

Under the Council Directive 1999/74/EC, housing systems for laying hens are categorized as enriched cages, not enriched cages or non-cage systems. Since January 1, 2002 all enriched cages must provide at least 750 cm^2 of cage area per hen, 600 cm^2 of which must be usable space. The height of the cage for areas of the cage not considered usable floor space must be at least 20 cm (Blokhuis, 2004; Europa, 2005c), and usable floor areas must be at least 40 cm high (Blokhuis, 2004). Total cage area must be at least 2000 cm^2. Enriched cages must provide a nest, litter to allow pecking and scratching, and at least 15 cm of perch space per hen. Each hen must have unrestricted access to feed, access to at least 12 cm of feed trough length and access to at least 2 nipple or cup drinkers (Blokhuis, 2004; Europa, 2005c). Cages must include claw-shortening devices and the slope of the floor must not exceed 14% (Blokhuis, 2004). Aisles must be at least 90 cm wide and bottom tier cages must be at least 35 cm from the floor to facilitate inspection of the facility, and bird population and depopulation (Europa, 2005c).

As of January 1, 2003, all non-enriched cage systems in the EU are required to provide hens with at least 550 cm^2 of cage area. Feed trough and drinking channels must be at least 10 cm in length, or at least two drinkers or cups must be available per hen for drinking. A minimum of 40 cm of cage height is required over at least 65% of the cage, and cage height may not be less than 35 cm at any position. Floor slopes may not be higher than 14% or 8 degrees, and suitable claw-shortening devices must be provided. Not enriched cage systems may not be built or utilized for the first time after January 1, 2003, and all non-enriched systems will be prohibited as of January 1, 2012 (Europa, 2005c).

As of January 1, 2002 and January 1, 2007, all newly built and previously existing non-cage systems, respectively, must provide at least 10 cm of linear or 4 cm of circular feeder space per hen, and either 2.5 cm of continuous drinking trough or 1 cm circular drinking trough space per hen. Alternatively, at least one nipple drinker or cup must be available for every 10 hens. Systems must provide at least 1 nest site for every 7 hens, or a minimum of 1 m^2 for every 120 hens when group nests are used. A maximum stocking density of 9 hens per m^2 usable area is allowed unless the usable area corresponds to available floor surface, in which case a stocking density of 12 hens per m^2 is permitted until December 31, 2011 (Europa, 2005c).

Perches may not be positioned above the floor litter, must be distanced at least 20 cm from walls and 30 cm apart, must provide at least 15 cm per hen and may not have sharp edges. The litter area must occupy at least one third of the floor surface and must provide each hen with least 250 cm^2 of littered area. Systems may be 4 tiers high at the most, the headroom between tiers must be at least 45 cm high, and feeders and drinkers must be positioned such that all hens have equal access to feed and water. Tiers must be positioned such that fecal matter does not fall onto lower levels and all floor surfaces must adequately support the forward-facing claws of both feet (Europa, 2005c).

For open run areas, hens must have access to several pop holes along the length of the barn. Pop holes must be at least 35 cm high and 40 cm wide, or a total of 2 m opening width must be available for each group of 1000 hens. Open runs must provide adequate area for the stocking density and to prevent ground contamination, and must provide shelter from predation and weather conditions. All member states must implement monitoring policies to ensure compliance with the Directive (Europa, 2005c).

In 2005, the European Commission began to prepare a summary report of the various housing systems described under the directive, based upon SVC evaluations. The report considered pathological, physiological and ethological impacts of the different systems on hen health and welfare, as well as environmental impacts and socio-economic implications. The proposal for future directives was submitted to the Council in 2008. Notably, no changes to the 1999 Laying Hen Directive were recommended (EC, 2008).

6.2.3 EU Salmonella Control Program

The EU has also formulated directives to control food borne zoonoses such as Salmonella. Regulation (EC) No 2160/2003 concerns the control of Salmonella and other specified food-borne zoonotic agents and stipulates minimum sampling requirements for agricultural species and food sources. According to the policy, all suspected cases of Salmonella infection in a poultry house must be reported to a competent authority, and all birds must be slaughtered if contamination is confirmed. Barn and equipment disinfection and manure disposal must be carried out in accordance with local veterinary authority requirements. Repopulation may not occur until local authority testing requirements are satisfied. Hatching eggs must be destroyed or considered high-risk product. Non-incubated eggs must either be immediately destroyed, or marked and heat treated by an authorized processor. Under the European Union Directive 92/117/EEC, 50% of the costs associated with slaughter and destruction are financed by the European Commission (Wilk et al., 2000).

Sampling of breeding flocks must be conducted by an authorized national laboratory, and costs are incurred by the owner of the flock. For rearing flocks, crate liners and dead birds must be tested at day 1, and pooled fecal samples from several random barn locations must be analyzed when the birds are 4 weeks old and again 2 weeks before onset of lay. Pooled fecal samples are tested every 2 weeks for adult breeding flocks. Breeding flocks whose hatchery incubator capacity exceeds 1000 eggs must also be tested at the hatchery. Tests may either be conducted on pooled meconium samples from 250 chicks or 50 dead-in-the-shell-chicks (Wilk et al., 2000; Europa, 2005d).

During the rearing period, laying flocks must also be tested as day old chicks and again 2 weeks before birds are transferred to the production unit. During the laying period, hens must be tested every 15 weeks (Wilk et al., 2000; Europa, 2005d).

6.2.4 Summary and Conclusions

The European Union was first established in 1950 to promote integration between democratic European nations. By 2007, the EU grew to include 27 member states, all of which are included in the Common Agricultural Policy. The CAP emphasizes a common European market where direct producer payments ensure quality and safety of reasonably priced food products, guarantee fair farm incomes, protect the environment and sustainable production, and ensure compliance with animal welfare standards.

Member states are required to implement minimum EU directives through nationally enforced legislation, and to ensure compliance with legislative policies. The EU Laying Hen Directive 1999/74/EC9 was approved in July 1999 and will prohibit the keeping of laying hens in non-enriched cages as of 2012. At this time, only enriched cage and non-cage systems that provide hens with nests, perches and litter facilities will be permitted in the EU. To control food borne zoonosis such as Salmonella, the EU has introduced additional directives.

An extensive evaluation of new housing systems was requested by the Commission beginning in 2005, and the impacts of enriched and non-cage systems on bird welfare, the environment and socio-economic factors was assessed. Based upon these findings, a proposal regarding possible changes to the layer hen directive was submitted to the European Council in early 2008. The Commission concluded that sufficient scientific and economic evidence existed to maintain the EU ban on conventional battery cages as of 2012 (EC, 2008).

6.3 Introduction to the Netherlands

The Netherlands is a small, relatively flat country with a total area of 41,526 square kilometres (Encarta, 2004a; USDS, 2004). The Netherlands derives its name from the Dutch word neder, meaning low, in reference to the fact that over one third of the country lies below sea level. Elevation in The Netherlands generally does not exceed 50 m and is fairly uniform throughout the country. Since the middle ages, the Dutch have constructed dikes to control water levels and form reclaimed land areas, known as polders, and over 2000 square kilometres of new land has been generated in this way (Encarta, 2004a).

The Netherlands is almost 1/6th the size of the province of Alberta, but in 2004 recorded a population of 16,318,199 inhabitants, more than 50% of the population of Canada. With a population density of approximately 481 persons per square kilometre, the Netherlands ranks among the most densely populated countries in the world (Encarta, 2004a; USDS, 2004). Almost 90% of inhabitants reside in urban centres (Encarta, 2004).

The climate in The Netherlands is primarily influenced by its coastal location, and varies very little across the nation due to the absence of natural barriers, uniform elevation and the small land base. Winters and summers are mild and temperatures generally range between -1° to 5°C in the winter, and 13° to 22°C during the summer months. The annual precipitation ranges from 690 mm along the coast to 770 mm in the central region, and most days are cloudy. Prolonged frost is uncommon (Encarta, 2004a).

The majority of land in The Netherlands is dedicated to agricultural production and approximately 3% of the labour force is involved in agricultural, forestry and fishing sectors. In spite of the small land area and dense population, The Netherlands is one of the world's leading agricultural exporters of meat, dairy products, eggs, flowers and vegetables, and is the highest net contributor to the EU (Encarta, 2004a; USDS, 2004).

The Netherlands is governed by a parliamentary democracy, headed by the Prime Minister. The Dutch Monarch acts as the symbolic head of state and appoints cabinet Ministers and State Secretaries, who initiate, implement and amend legislation. The country is divided into 12 provinces that are governed by provincial councils and an executive appointee. Provinces are further divided into 467 municipalities and 37 water districts that regulate water management. Agricultural legislation follows national, provincial and municipal policies, as well as guidelines stipulated by product boards (USDS, 2004; Wikipedia, 2004a).

Trade and industrial efficiency, and intensive land use and reclamation have enabled Dutch economic growth and a high standard of living, and are sustained by policies regarding energy conservation, environmental protection, and regional development. The Netherlands was the first European nation to introduce a national strategy for sustainable development, targeting policies such as agricultural production, alternative energy sources and pollution (Encarta, 2004a; USDS, 2004). For example, by 2010, the government is aiming to reduce pollution in The Netherlands by 80-90%, to ensure a clean environment for future generations. To implement these policies, the government works in close association with industry and non-governmental institutions (USDS, 2004). Dutch policy promotes human rights and democracy, and the Dutch are renowned for their innovative and proactive mentality, an attitude that is also apparent in the Dutch approach towards animal welfare (Encarta, 2004a; Wikipedia, 2004a).

The Netherlands relies heavily on export and import markets and has established an excellent reputation for world trade. Germany is The Netherlands's principal trading partner (Encarta, 2004a). The Dutch are also active participants in international collaborations and are involved with organizations such as the United Nations, the World Trade Organization and the International Monetary Fund (Encarta, 2004a; USDS, 2004). The Netherlands was one of the original 6 countries to join the EU in 1950, and has developed a Foreign Policy that prioritizes European integration, security and stability (USDS, 2004).

6.3.1 Dutch Egg Production

There are approximately 30 million laying hens in The Netherlands (van Emous, 2004). In 2004, Dutch laying hens produced 9.2 billion eggs, more than 65% of which were exported in shell form or as secondary product. Germany is the primary export market for Dutch eggs and egg products (IEC, 2005).

Egg consumption has increased in the Netherlands to approximately 181 eggs per person (IEC, 2005). Approximately one third of these are consumed as table eggs, while the remaining two thirds are used as ingredients in products such as baked goods and shampoo. In The Netherlands, as in many European countries, brown eggs are preferred over white-shelled eggs (van Emous, 2004).

In the spring of 2003, an outbreak of AI occurred in the central province of Gelderland where approximately one third of all Dutch poultry production is concentrated (Harris, 2003; van Pelt et al., 2004). The Dutch Ministry of Agriculture enforced a precautionary exclusion zone, requiring all birds within a 10-km radius of an infected farm to be destroyed, regardless of whether these birds tested positive for AI or not (Harris, 2003; van Pelt et al., 2004). The mass culling of 30 million poultry resulted in a shortage of eggs in the Netherlands and imports were purchased from Germany, Italy and Spain (van Pelt et al., 2004). Despite of the AI devastation of 2003, Dutch egg producers were able to resume 2002 production levels by 2004 (IEC, 2005).

More than 50% of laying hens in the Netherlands are housed in non-cage alternative systems including barn, free range and organic production facilities (van Emous, 2004; IEC, 2005). Aviary systems account for over 50% of alternative layer housing production (Figure 6.1) (van Emous, 2004). Covered outdoor access areas known as wintergardens are also becoming increasingly popular, and are often combined with barn systems to provide outdoor range access (Figure 2) (van Emous, 2004; Aviary, 2004). In 2001, approximately 100,000 hens were housed in organic systems. Organic producers may keep anywhere from a few hundred to 8000 hens, and the average organic farm houses 4000 birds (Fiks-van Niekerk, 2001).

As a member of the EU, The Netherlands follows the labeling code stipulated by the EU directive (2002/4/EC) and requires registration of all production facilities. Eggs are labeled with NL, representing the country code, as well as the production trace number, and the housing type number. Organically produced eggs are coded by a 0, eggs produced at free range aviary and deep litter systems that include outdoor access are considered 1 eggs, and eggs from indoor floor facilities are labeled with the number 2. Producers do not receive a premium price for eggs from enriched cage systems since these eggs are labeled with the number 3 and are not distinguished from eggs laid in conventional, not enriched cage systems (van Emous, 2004).

6.3.2 Dutch Salmonella Control Program

In 1989, the Dutch government and poultry producer boards implemented a monitoring and control program to target breeding flock sources of Salmonella contamination. The primary goal of the program was to ensure that layer and broiler chicks arriving on farms were free from Salmonella infection (van de Giessen et al., 1994). Codes for hygienic practices at all levels of poultry production were also outlined (van de Giessen et al., 1994), and in 1992 were integrated with the new European Zoonosis Directive (EC/92/117) established for EU member states.

To further target salmonellosis, a three-year strategic plan outlining maximum acceptable infection levels in Dutch layer and broiler flocks was introduced in 1997. For laying hens, a goal was set for 5% of live flocks by the end of the year 2000. The program included regular, compulsory testing of flocks using bacterial cultures or serological tests, hygienic requirements emphasizing management, biosecurity and rodent control for each stage in the production cycle, and measures required in the event of positive-testing flocks. Depending on the Salmonella serotype identified, the age of the birds and the stage in the breeding cycle, birds would either be slaughtered or treated with antibiotics. To prevent contamination of future flocks, cleaning and disinfection of facilities, and negative environmental tests for Salmonella were also required prior to repopulation (Intervet, 2004).

By 2001, implementation of the strategic program had resulted in only limited reductions in Salmonella contamination of rearing and laying flocks, and target goals had yet to be reached. For example, whereas in 1997 14.2% of laying flocks in the Netherlands had tested positive for *Salmonella enteritidis*, 9.1% of flocks tested positive in 2001. Additional measures were implemented including mandatory testing of all flocks on a farm in the event that one flock tested positive, vaccination of all future flocks on the farm, and heat treatment of eggs obtained from positive-testing flocks. High costs associated with positive testing have encouraged producers to adopt vaccination as a prophylactic measure. In 2002, over 80% of layer flocks were vaccinated against Salmonella (Intervet, 2004).

In 2003, the incidence of positive tests for *Salmonella enteritidis* increased in the Netherlands. The contamination appeared to be linked to imported egg sources, which had increased as a result of the AI outbreak. The potential human health risk associated with changes in market supply became apparent, and the Dutch National Salmonella Centre strongly recommended stringent monitoring of imported egg sources. The occurrence further reiterates the need for a uniform system of monitoring and controlling Salmonella across EU member states (van Pelt et al., 2004).

6.3.3 Welfare and Housing Legislation in The Netherlands

Public concern for animal welfare has been increasing in the Netherlands since intensification of livestock production began in the 1960's. The Dutch Animal Health and Welfare Act of 1992 reflects a growing awareness of the intrinsic value of animals, and applies to all vertebrate species kept by humans. The Act provides general guidelines for the keeping of animals, and prohibits actions that cause unnecessary pain or injury, or those which damage the health or welfare of a domestic or wild animal. In The Netherlands, it is illegal to withhold essential care from an animal, to perform surgical operations that are not permitted by law, or to present animals as a prize, gift or reward. Minimum guidelines for housing animals, slaughter procedures and animal transport are also outlined (LNV, 2004).

As a member of the EU, The Netherlands is required to adopt the EU Council Directive 1999/74/EC regarding the minimum standards for the protection of laying hens. Consequently, as of 2012, only enriched cage and non cage systems will be permitted for housing layer hens, as outlined in the EU directive (Europa, 2005b). Beak trimming is currently permitted in The Netherlands, provided it is performed before birds are 10 days of age. Plans to prohibit the procedure as of 2007, with the exception of a 10-year grace period for producers who made the transition to alternative systems prior to 2007 (van Emous, 2004), have since been postponed.

Egg washing and oiling are not permitted in The Netherlands. Floor and dirty eggs are labeled as second grade product and are further processed (Bock, 2004). For non-cage systems, egg labeling must take place at the production facility, to ensure the correct housing type number is recorded on the egg. However, for caged hens, eggs may be labeled at the packing station, where candling and grading are also carried out (Bock, 2004). Free range facilities with outdoor access and organic operations must allow birds the opportunity to range outside between 1100 and 1700 h (van Emous, 2004).

Organic animal production in the Netherlands must follow Council Regulation (EEC) No. 2092/91, concerning the production and processing of organic plants, as well as Council Regulation (EC) No. 1804/99, a supplementary set of guidelines for livestock production (Fiks-van Niekerk, 2001; Melita, 2001). For laying hen operations, pullets must be reared organically and must have access to outdoor range by 7-8 weeks of age (Bock, 2004). Although beak trimming of organically housed birds is not permitted, slight beak-burning, which involves touching the beaks of the birds to hot metal, is currently permitted during week one (Bock, 2004). Hen feed must be comprised of 80% organically derived ingredients and in the near future, this will change to 100% organic feed requirements. Hens must have access to an open water source such as a cup system, so that birds are able to drink in a natural manner (Bock, 2004). Housing standards require no more than 6 hens per square meter floor space and 120 square centimetres per hen nest box area (Figure 3) (van Emous, 2004). A maximum of 3000 birds can be housed together. Since this applies to all access areas, sectional division is required inside the barn, in wintergardens and on outside range (Bock, 2004). Compliance with these regulations is assessed by Skal, a government-appointed inspection body (Melita, 2001).

6.3.4 Incentive for Change to Alternative Housing Systems in The Netherlands

The Dutch government actively encouraged producers to switch from battery cage production to deep litter and aviary systems even before the 1999 EU laying hen directive banning conventional systems by 2012 was implemented (van Emous, 2003), and has continued to adopt policies to encourage this transition. For example, although the EU egg labeling system classifies all cage eggs as category 3 products, the Dutch government has not further mandated a distinction between enriched cage eggs and conventional cage eggs. Consequently, market prices are identical for both products, even though the cost of production of enriched cage eggs is higher. This has discouraged investment in enriched cages and encouraged producers to adopt non-cage alternative housing systems such as aviaries, for which investment costs are lower and egg prices are higher (van Emous, 2004).

To further promote laying hen welfare, the Dutch government was intending to implement a ban on beak trimming as of 2007. Legislators however are aware of the difficulties that may arise when large groups of non-beak trimmed birds are housed together, particularly if producers are not accustomed to managing birds in non cage systems. Therefore, the government initially proposed to allow a 10-year beak trimming grace period for producers who changed to alternative systems prior to 2007. This policy would have allowed producers to adjust to new management strategies without the additional challenges of managing non beak trimmed birds, thereby encouraging producers in The Netherlands to change housing systems prior to the 2012 EU deadline (van Emous, 2004). Plans to prohibit the procedure as of 2007 have however now been postponed.

Increasing concern for issues such as food safety, disease emergence, manure disposal, food surpluses and falling prices in conventional agriculture have generated both consumer and producer interest in organic farming (Melita, 2001). The Dutch government has fostered this interest by developing an action plan to increase organic production to 10% by the year 2010 (Fiks-van Niekerk, 2001; Melita, 2001). To encourage conversion to organic production and help producers overcome the transition, the government initially created a subsidy program. However, interest in converting was so high that the number of applications submitted for assistance exceeded the number available for funding. While the government no longer provides direct financial support for conversion to organic farming, a number of other incentive programs have been established. For example, organic farmers and industries are able to borrow money at a lower interest rate, provided the loan will fund sustainable projects. Since 2000, a tax-free deductible of up to 10,227 Euro is allowable for organic producers who generate at least 70% of their income from selling organic products. The Dutch Ministry of Agriculture has also requested financial support from the European Union for sustainable agricultural production, and since 1995, the Ministry of Housing, Spatial Planning and Environment has encouraged investment in organic farming, marketing and processing by eliminating taxation of interests and dividends generated from organic investments (Melita, 2001).

Organizations such as the Federation of Organic Farmers (Federatie van Biologische Boeren, FBB) have also been established in the Netherlands, to support the interests of the farmers. The FBB strives to uphold fair prices for organic products, inform consumers and thereby increase demand for organic goods, improve national and EU legislation regarding organic production, and preserve the natural value of and approach to organic agriculture. Compliance with organic regulations is controlled by Skal, whose main goal is to guarantee quality and reliability in certifying organic production. The success of organic production in the Netherlands is becoming apparent from the increasing consumer demand and growing market share for organic goods, as well as increasing number of organic processors (Melita, 2001).

6.3.5 The Dutch Experience with Alternative Layer Housing Systems

6.3.5.1 Enriched Cages

Research involving enriched cages began in The Netherlands in 1993 (Fiks-van Niekerk, 2001; Fiks-van Niekerk et al., 2002) and initial trials focused on modifying conventional battery systems as well as developing new enriched cage systems (Fiks-van Niekerk, 2002). Although the Dutch government supported and encouraged this research, the results highlighted a number of technical difficulties with enriched cage systems (van Emous, 2004). For example, from an economic standpoint, cage systems capable of housing larger group sizes ranging from 8-50 hens were more preferable than smaller group units, since larger cages would enable the most efficient use of barn space. Larger cages would also provide birds with more usable space and therefore increase freedom of movement, which was beneficial for the health and welfare of the hens. However, observing birds, feed intake, and depopulation were more difficult to manage, and feather pecking and aggression were more prevalent in large, confined groups (Fiks-van Niekerk et al., 2002).

Results also outlined the positive aspects of enriched cages. Productivity in enriched cages equaled or exceeded results from conventional systems, and hens used facilities extensively. It became apparent that an automatic closing system was not necessary for nest boxes, and when access to the litter facility was limited to the last 3-5 hours of the day, very few eggs were laid in the litter (Fiks-van Niekerk et al., 2002). In spite of these findings, high start-up costs, low egg prices, and low stocking densities have discouraged investment in enriched cage systems in the Netherlands (van Emous, 2004).

6.3.5.2 Experiences with Aviaries and Floor Systems

Aviaries are the most predominant housing system in The Netherlands (van Emous, 2003). Since aviaries utilize the third dimension of the barn, the systems enable high stocking densities, which is economically preferable for producers (van Emous, 2004). Deep litter systems are also becoming increasingly popular and are generally easier to manage than aviaries since an overview of the entire production unit is possible. Use of barn third dimensional space is also achievable in deep litter systems by building multiple floors within a barn, each of which houses a separate deep litter system (van Emous, 2004).

Managing aviaries and deep litter facilities is very different from managing conventionally caged birds, and a number of difficulties must be overcome for production to be successful. Ammonia and dust levels may be higher, and risk of disease outbreak may be increased if manure is not adequately managed. Labour requirements are increased, and production can be affected by high numbers of floor eggs, or problems with aggression, feather pecking and cannibalism (Fiks-van Niekerk, 2002; van Emous, 2003). Rearing birds on floor systems may also require additional labour and capital investment (Fiks-van Niekerk, 2002). However, production is improving in non-cage systems as producers gain experience managing birds and facility designs are refined.

Studies comparing enriched cage systems to conventional housing and non-cage systems, and examination of commercial aviary production data suggest that while the energy requirements of birds in alternative facilities are higher and may result in higher feed intake (Fiks-van Niekerk, 2002), hen housed production in aviary and deep litter systems is equal to or exceeds production of caged hens (Fiks-van Niekerk, 2002; van Emous, 2003). Producers also obtain higher prices for non-cage eggs (van Emous, 2004). Egg quality in alternative systems is comparable to, and may exceed egg quality in conventional cages (van Emous, 2003). At a commercial aviary visited in The

Netherlands, medium-bodied hens weighing close to 2 kg consumed approximately 125 g of feed daily. Hen production averaged 93% at 36 weeks, egg weight averaged 66g and approximately 2% of eggs were floor laid (Aviary, 2004).

Fiks-van Niekerk (2002) found the overall health of commercial aviary birds to be very good. While 68% of flocks required treatment for worms, coccidiosis was not problematic when litter was kept dry, and mortality was lower in aviaries than in conventional cages. Hen mortality at a Dutch commercial aviary visited averaged 2% (Aviary, 2004). Hens in aviary systems had stronger bones than caged birds, which helped to prevent bone breaks during depopulation and transport (Fiks-van Niekerk, 2002).

A survey of 17 commercial aviary systems with winter garden and free range outdoor access found that hens used covered range areas more frequently than uncovered range (van Emous and Fiks-van Niekerk, 2004). Mortality rates for outdoor range operations however, were very high, ranging from 5-14 %, and were primarily attributed to *Escherichia coli* infections, flocking, predation, amyloidosis and burnout (van Emous and Fiks-van Niekerk, 2004). Mortality rates at one organic farm visited in The Netherlands were approximately 7%, 3% of which was attributed to predation by foxes and birds of prey (Bock, 2004).

Between 2001 and 2002, the Research Institute for Animal Husbandry conducted a survey of all Dutch commercial aviaries with free range access. The incidence of floor eggs averaged 2.0% and ranged from 0.4% to 5.6%. This improvement over the 1996 survey of 3.5% floor eggs was attributed to better management of aviary systems and improved layout design, since more floor eggs were found in older systems (van Emous, 2003).

Egg sizes may differ if birds with access to free range consume different amounts of feed (van Emous, 2004). Most recently, producers have noticed that shell colour is often lighter when hens have access to free range. While the exact cause of lighter shells has not yet been determined, producers speculate that eating grass, exposure to sunlight or stress may contribute to discolouration (van Emous and Fiks-van Niekerk, 2004). Kris Bock (2004), an organic Dutch producer, also attributed shell lightening to health-related stress, noting that diseased birds typically lay lighter coloured eggs. Since whiter eggs are downgraded to second grade eggs in The Netherlands, shell lightening has negative consequences for producers (Bock, 2004).

6.3.6 Management strategies

Experience with non-cage layer hen housing systems has taught producers and researchers that a number of useful strategies can be adopted to improve production, reduce labour requirements, and improve the quality of both the environment and the overall housing experience. Producers agree that monitoring the birds carefully, learning from their actions and anticipating birds' needs is essential for successful production (Aviary, 2004; Bock, 2004).

6.3.6.1 Rearing Period

The rearing period is a critical learning stage for pullets, and rearing birds in systems that closely resemble their future housing environment will facilitate the transition to production housing (van Emous, 2003). Raising birds in aviary systems for example will teach birds to use the three dimensional space of the system, teach them to direct pecking at the ground rather than at other hens (Aviary, 2004; Bock, 2004), and will expose birds to nest facilities early, thereby discouraging floor laying when the birds are transferred to production units (van Emous and Fiks-van Niekerk, 2004). Exposure to free range during rearing will also encourage later use of range access (van Emous and Fiks-van Niekerk, 2004).

When day old birds are placed in aviary systems, laying paper on the wire floor will facilitate walking and thereby encourage exploration (Aviary, 2004). Locking birds within the system for the first 2-3 weeks will further encourage discovery (Figure 4) (Aviary, 2004; van Emous, 2003). During this time, drinkers should be available on the bottom tier of the aviary, however the water supply should be halted at the lowest level by 10 weeks of age at the latest. By this time, birds will be familiar with the system but should be encouraged to move upwards to eat and drink (Aviary, 2004; van Emous, 2003). Drinkers should be made available at the same level where nest boxes are found, to acclimatize birds to the nesting area (Aviary, 2004). To ensure that birds continue to eat and drink when they enter the production environment, feeders and drinkers should be positioned in the same location for rearing and production units, and colour coding systems should also be the same (van Emous, 2003). Providing stairs and perches will facilitate movement throughout the system (Aviary, 2004).

Producers stress that teaching the birds to enter the system at night is critical (Aviary, 2004; Bock; 2004). Birds that are positioned in the aviary in the morning will be less likely to lay floor eggs when they begin production. Overnight positioning within the system will also ensure that fecal matter accumulates on the manure belts, from where it can be removed, rather than on the floor. Physically placing birds into the system at night between the ages of 6-8 weeks may seem labour intensive, but will prove to be an important investment of time. Furthermore, some strains of birds are very clever and will learn this behaviour in less than 2 weeks (Aviary, 2004).

Before transferring birds to production units, producers should ensure that hen body reserves are adequate. Hens that begin their production period at a low body weight are particularly susceptible to burnout in alternative systems, due to the energy expenditure associated with increased movement (van Emous, 2003). Beak trimming before the birds are 10 days of age will also minimize interference with weight gain, and delaying light stimulation will encourage weight gain during the rearing period (van Emous, 2003). Finally, some producers find it beneficial to enclose rearing aviaries with wire roofing, to facilitate bird catching for transfer to production units (Aviary, 2004).

6.3.6.2 Transition to the Laying Period

Birds should be transferred to production units no later than 17 weeks of age. This will allow enough time for birds to explore their new system and locate the nesting sites before the majority of hens begin to lay, thereby discouraging floor and system laying (van Emous, 2003). If possible, birds should enter the new system in the morning, so that a full day is available for inspecting the facility and finding food and water sources. Additional daylight should be provided if birds are moved in the afternoon. Initially increasing the temperature of the facility will aid the recovery of birds that have experienced stress during transport, and will encourage hen distribution throughout the system. Producers should monitor birds carefully for dehydration. Light intensity should be at least 20 lux and should match lighting levels of the rearing unit during the first week (van Emous, 2003).

6.3.6.3 Housing Layout and Division

Creating a barn and range layout that promotes harmony in the flock is very important for production (Fiks-van Niekerk, 2001; Bock, 2004). Areas should be designated for specific activities such as nesting, feeding, movement, bathing/scratching and resting (Fiks-van Niekerk, 2001; Bock, 2004). Birds will learn to use the areas for the activities intended, which will minimize interruptions, and thereby reduce frustration and aggression (Bock, 2004). Designated areas will also promote bird distribution throughout the barn and thereby reduce mortalities related to flocking (van Emous, 2003).

Division of the barn and range areas into smaller functional units will further serve to minimize aggression and pecking, without compromising bird movement (Bos et al., 2003). For example, one Dutch aviary facility housed 18,000 in a barn that was divided into 4 sections of 4500 birds (Aviary, 2004). An organic production facility housing 6000 birds divided indoor and outdoor areas into 2 sections of 3000 birds (Bock, 2004). Divisional sections also serve to reduce crowding (Bock, 2004).

6.3.6.4 Nest Use

Drinking systems should be provided in front of or close to nesting sites so that hens will not be drawn away from the nests to drink (Figure 5) (van Emous, 2003; van Emous and Fiks-van Niekerk, 2004). Hens should have access to nest boxes at least 2 hours before barn lights are turned on, and a closing system at night will serve to reduce nest box soiling, thereby improving egg quality (van Emous, 2003). Nest boxes should be closed at least 1 hour before lights are shut off, to allow hens sufficient time to settle for the night (van Emous, 2003). Simulating dawn and dusk lighting further encourages birds to calmly settle (van Emous, 2003; van Emous and Fiks-van Niekerk, 2004).

Hens should be trained to use the nest sites at a young age. By physically placing birds inside the nest box, should hens attempt to lay elsewhere, hens will eventually recognize the intended use of the nest box and will also be aware of the presence of the producer in the barn (van Emous, 2004). Frequent collection of floor eggs is also necessary to discourage other birds from laying their eggs in the same location (van Emous, 2003; Aviary, 2004; Bock, 2004; van Emous and Fiks-van Niekerk, 2004). Placing floor and system eggs inside the nest boxes where they are visible to other hens will aide other birds in finding the nesting sites (van Emous, 2003).

Birds often prefer the first and highest nest boxes, and will delay oviposition if these sites are in use. This may result in an increase in the incidence of floor eggs. Therefore, uniform distribution of the birds throughout the house is necessary to prevent nest box queues (van Emous, 2003; van Emous and Fiks-van Niekerk, 2004). Furthermore, nest boxes should provide at least 100 square cm per bird to ensure sufficient nesting space (van Emous, 2003).

Adequate lighting for lower level nest boxes will also help to prevent floor laying (van Emous, 2003). Rope lighting has proven to be an inexpensive yet effective form of providing uniform, low level lighting for nest boxes and other darkened areas in the housing system (Figure 6) (Bock, 2004; van Emous, 2004). In The Netherlands, it is also permissible to use electric wire to deter hens from laying eggs in certain areas (van Emous, 2004).

6.3.6.5 Natural Vertical Tendencies

Aviary systems are designed to encourage the natural vertical tendencies of birds (Bos et al., 2003). Systems are built to facilitate upwards movement, and provision of ladders, perches and bridges will further help birds ascend (van Emous, 2003; Aviary, 2004). Tiers should be staggered in a zigzag manner and nests should be vertically integrated within the system to promote upward movement and distribution of birds. The distance between systems should not exceed 1 m (van Emous, 2003). Provision of feeders and drinkers at different levels will also encourage bird distribution and will enable hens to choose from amenities at different levels (Bos et al., 2003; Aviary, 2004). Dawn and dusk lighting simulation and dimming lights from the floor level upwards will foster vertical movement at night, as birds seek resting areas that are high up and safe from predation (van Emous, 2003; Bos et al., 2003).

6.3.6.6 Air Quality

Encouraging bird movement into the aviary system also serves to limit manure accumulation in the litter. According to Bos et al. (2003), when hens spend the majority of their time within the system, approximately 90% of fecal matter can be captured on manure belts. In a typical aviary system however, the remaining 10% of fecal matter can potentially produce 90 g of ammonia emissions per year (Bos et al., 2003). This level can be reduced to 20 g per year with new ventilation systems that enhance water evaporation, and by encouraging hens to scratch and bathe, since these activities rotate the litter and further promote drying. Scratching can be stimulated by spreading wheat or grain (Figure 7) (Bock, 2004; Bos et al., 2003), and a thin layer of sand is sufficient to encourage bathing activity (Aviary, 2004). Emissions are also reduced by cleaning manure belts frequently (Aviary, 2004; Bos et al., 2003), which minimizes the time manure is exposed to air, and by controlling manure and litter composition. Drying systems that blow warm air over the manure belts and reduce gas emissions are used in many cage systems (Bos et al., 2004), and might also be transferable to aviary systems. Finally, feeding and drinking systems should not be located in the litter area since this would increase water and fecal matter levels in the litter (van Emous, 2003; Aviary, 2004).

6.3.6.7 Production

Stimulating scratching, searching and litter pecking by spreading wheat, grain, or shells each day will increase bird interest in the floor substrate (Bock, 2004; Bos et al., 2003). Limestone blocks, wood shavings and straw bundles can also be provided (Aviary, 2004; Bock, 2004; van Emous, 2004). Hens that are preoccupied have less motivation and less opportunity to peck at conspecifics, and as result, the incidence of feather pecking and aggressive pecking is reduced. A lower incidence of feather pecking also reduces the occurrence of cannibalism, and hence morbidity and mortality rates also improve by enhancing the attractiveness of the litter (Jendral and Robinson, 2004). Furthermore, healthy plumage condition is essential for promoting efficient feed conversion, especially in aviary and range systems where feed requirements tend to be higher because of increased movement and energy expenditure. Tauson and Svenson (1980) determined that maintenance requirements were increased by 46% for poorly feather covered birds, resulting in a 27% higher feed consumption requirement.

Flock uniformity can be enhanced by feeding birds frequently, and by distributing feed at multiple locations (van Emous, 2003; Aviary, 2004). Running feed systems often, for example every hour in the morning and every two hours in the afternoon (Aviary, 2004), and at many sites will help to prevent flocking, overcrowding and aggression at the feeders (van Emous, 2003). Bock (2004) has also found that feed consumption is typically lower for hens with access to outdoor range, likely because birds are consuming range plant and insect matter.

6.3.6.8 Outdoors: wintergarden and free range

Creating an attractive and protected outdoor area is necessary to encourage hens to range, and extensive use of outdoor areas will reduce feather pecking in the flock (Fiks-van Niekerk, 2001). A windbreak should be provided immediately adjacent to the doors, so that birds are not discouraged from venturing out of the barn or wintergarden (Bock, 2004). Spreading substrate such as straw will also encourage birds to leave the barn area (Bock, 2004). The attractiveness of pasture areas can be increased by providing a variety of inexpensive substrates and plant matter that will serve both as pecking material and protective covering. Bock (2004) for example, deposits piles of woodchips immediately adjacent to his wintergarden area (Figure 7). Woodchips are available at no cost to this producer, are very interesting to the hens because they are filled with a variety of insects and worms, and unlike sand which can become very muddy, woodchips retain their attractiveness even when wet (Bock, 2004). Over the course of the laying cycle, hens breakdown the woodchips, spreading the remnants across the pasture area where short grasses are growing. Bock (2004) has next planted a wide row of bamboo shoots that are resilient to pecking by the birds and provide a sheltered area in the open field. An additional pasture and a row of trees complete the range area, which is completely surrounded by electric predator fencing. A wintergarden and a range layout are present on both sides of the barn so that outdoor access can be rotated to accommodate weather conditions, and to allow for pasture recovery (Figure 9) (Bock, 2004). Providing woodchips also deters the birds from excessive digging. Pasture and wintergarden areas should nonetheless be ploughed regularly (Bock, 2004; van Emous and Fiks-van Niekerk, 2004).

Initially, doors to the outdoor areas should be opened as late as possible to minimize ground egg laying. Once the hens have learned to use the nest boxes, doors can be opened earlier (Bock, 2004; van Emous, 2004). Hens will generally return to the barn by themselves at night, however leaving barns lights on will aide the birds in finding their way back. Feeding and drinking areas should also be made available in the wintergarden. Good body condition is necessary for birds that have access to outdoor areas. Birds will venture outside even in the winter when there is light snowfall (Bock, 2004).

6.3.6.9 Finding the Right Bird

Choosing the right breed of hen for a housing system is essential for successful production (Fiks-van Niekerk, 2001; Bock, 2004; van Emous, 2004). Non-aggressive, calmer strains of birds adapt better to non-cage and range systems (van Emous, 2004). For example, the Lohman Silver bird is a very calm, predominantly white feathering strain that is currently a favored breed in The Netherlands, Germany and Denmark (Tauson, 2004a). Lohman Silver hens produce brown eggs that are smaller, but uniform in size. Similar to a broiler in phenotype, these birds have a slightly higher feed consumption requirement than a light hybrid, but have hardy body condition making them ideally suited for range systems. Lohman Silver hens are not aggressive or flighty, exhibit a low incidence of feather pecking, and maintain excellent plumage cover (Tauson, 2004a; van Emous, 2004).

Hyline birds are also well adapted to aviary, deep litter and range systems. Hyline Brown hens are easy to handle, are not anxious, and exhibit low incidence of feather pecking and mortality. In commercial aviary and organic deep litter production birds consume approximately 120 g of feed per day, produce over 350 eggs in a 73-week period, and produce high quality, dark coloured eggs (Aviary, 2004; Bock, 2004).

6.3.7 Future Housing Systems in The Netherlands

Developing socially acceptable and responsible laying hen housing systems that synthesize the needs of the producer, the animal, the environment and the consumer requires cooperation and involvement of both the livestock industry and society. To conceptualize future housing systems that adequately address animal well being and environmental sustainability, while protecting the livelihood of the producer and food safety, a research group at Wageningen University and Research Centre in The Netherlands organized a "think tank" session for laying hen husbandry systems (Houden van Hennen, 2004). Poultry and feed producers, industry members, veterinarians, researchers, and consumers were invited to attend a forum to discuss the housing needs and demands of laying hens, the public and the farmer. Discussions were combined with workshops to generate creative solutions, and illustrators were present to capture ideas formulated. Intensive discussions revealed that members of the different sectors shared common beliefs and demands, and their wishes could therefore provide a foundation with which designs for new husbandry systems could be developed. By combining these wishes, the research team developed two unique proposals for potential future hen housing systems (Houden van Hennen, 2004).

The first design, the Roundel, consists of compact, circular housing system constructed around a central core. The central area is used for egg collection, sorting and viewing while the outer core area is divided into 12 segments. Each of 10 segments is capable of housing 3000 hens. The remaining 2 segments are used for collecting eggs, feed, and waste, and for storage. The housing units consist of a barn area for feeding, drinking, laying eggs and resting, and a foraging area, from which birds can access an outdoor climate-controlled range. Since the entire facility is constructed under one roof, hens do not have contact with outside birds and are not exposed to predation (Figure 10) (Houden van Hennen, 2004).

The second design, known as the Plantation is comprised of an inner yard where the housing units are located, and two outer fields that flank the housing area. The inner yard consists of a central foraging area surrounded by two buildings. One building contains eating, drinking and nesting facilities, while the other provides resting sites. Each building is divided into 10 units that functionally divide the entire inner yard into groups of 3000 hens. The inner yard is uncovered but can be enclosed during rain or emergency situations. Birds are free to travel throughout the entire system, and having been raised in this facility, are accustomed to the feeding, drinking, resting and nesting areas. The outer fields can be accessed from either building, and provide hens with additional foraging diversity. Outer areas are not covered by a roof, however bushes, trees and fields where crops such as corn can be grown provide protective cover from predation (Figure 11) (Houden van Hennen, 2004).

Variations and improvements to the design of either of the systems could be readily accommodated. In fact, the research team is hopeful that the Roundel and Plantation husbandry concepts will inspire additional innovations for future hen housing systems, and encourage individuals from all sectors to become involved with housing initiatives. In the defining process of this program, the importance of public contributions in formulating new housing concepts became apparent to the researchers (Houden van Hennen, 2004).

6.3.8 Summary and Conclusions

Despite its limited land base and dense population, The Netherlands has long adopted a proactive and innovative approach towards national and international issues, and in the process has become a leading contributor to European and international markets. An original founding member of the EU, the Netherlands has willingly complied with EU policies, and has exceeded these requirements by developing strategic action plans, incentive programs and national policies that promote pollution control, environmental sustainability, food safety, efficient production and animal welfare.

Animal welfare policies in The Netherlands reflect awareness for the intrinsic value of animal species. The Dutch government has encouraged the transition from traditional cage systems for housing layer hens, to alternative, non-cage systems, and by implementing a beak trimming policy that enables producers to adjust to the conversion, has demonstrated its support for both producer livelihood and hen welfare. Dutch consumers and societal groups have also communicated their intention to support the transition by encouraging supermarkets to ban the sale of eggs from caged hens.

Dutch researchers have investigated both cage and non-cage housing systems for laying hens, however aviaries have emerged as the preferred alternative housing system. Wintergarden and free range access are also becoming increasingly popular, and consumers and producers have developed considerable interest in organic farming. The government has fostered this interest by implementing incentive programs designed to facilitate the transition from conventional to organic agricultural practices.

Dutch experience with alternative housing systems for laying hens has provided considerable insight regarding improvements in facility design and management practices that can be adopted, to improve productivity and create a better working and living environment. Recommendations regarding rearing practices, transition to production units, system layout, nest use, encouraging natural behavioural tendencies, improving air quality and production, creating usable and attractive wintergarden and free range areas, and matching bird strains with housing environments will prove invaluable for producers who are either considering, or have already made the transition to alternative systems.

Dutch adaptability and receptiveness towards adversity, change and progress, and the success experienced as a result of this approach, are highly commendable and set an excellent example for production worldwide. Producers and consumers continue to strive to develop socially responsible housing systems for laying hens, and by working together have developed innovative constructs that may balance the needs of the laying hen, the producer, the consumer, the industry and the environment better than any system yet available.

6.3.9 Figures

Figure 6.1 Indoor aviary system in The Netherlands.

Photo courtesy J. S. Church

Figure 6.2 Dutch wintergarden (covered outdoor range).

Photo courtesy J. S. Church

Figure 6.3 Dutch organic floor litter system with access to wintergarden.

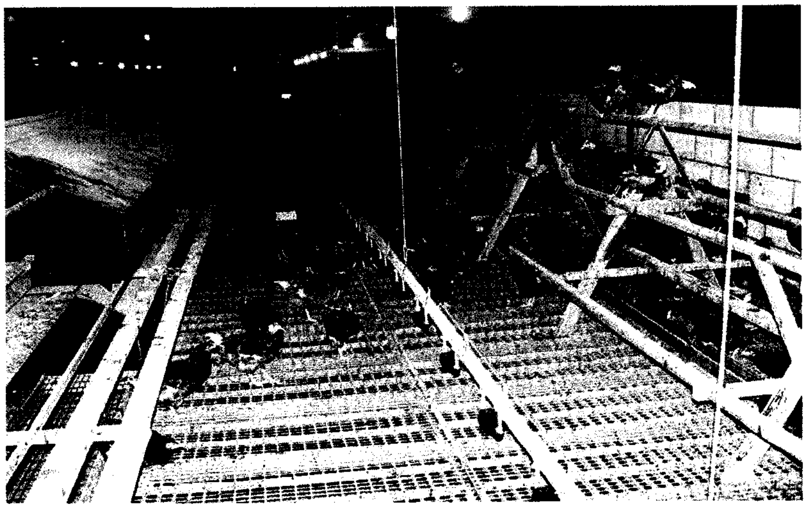


Photo courtesy J. S. Church

Figure 6.4 Dutch aviary producer demonstrating closing of pullet rearing system during first 2-3 weeks of rearing to encourage birds to explore their environment.

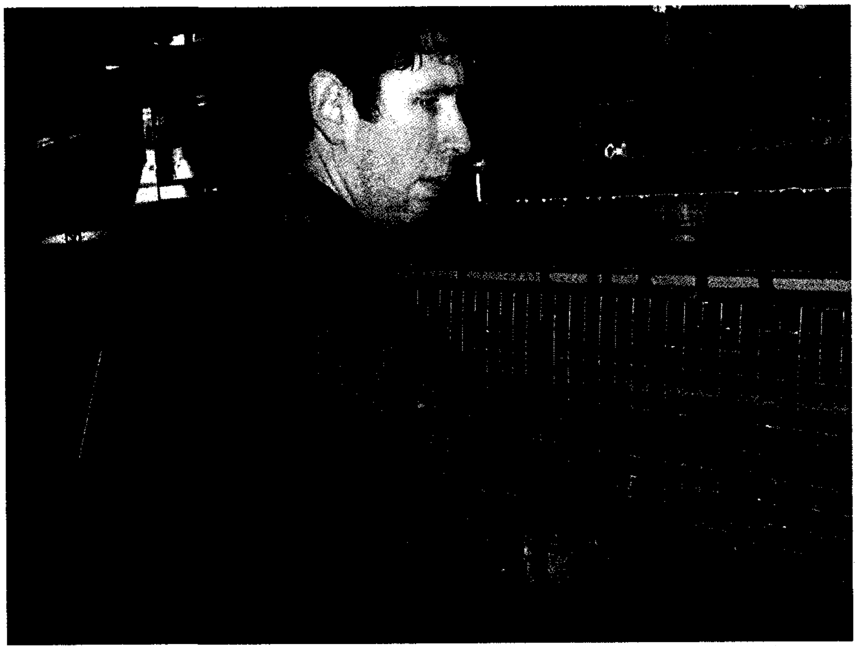


Photo courtesy J. S. Church

Figure 6.5 Providing drinking systems near nest sites reduces floor eggs.

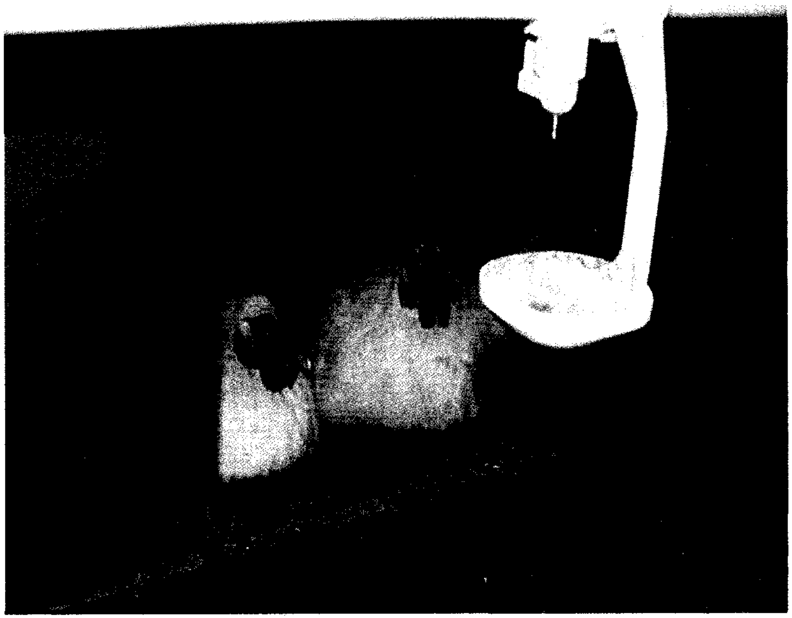


Photo courtesy J. S. Church

Figure 6.6 Rope lighting provides uniform, low level lighting for darkened areas in the housing system which reduces the incidence of floor laying.

Photo courtesy J. S. Church

Figure 6.7 Dutch organic producer preparing to spread grain over the system floor to encourage hens to peck and scratch at the ground.

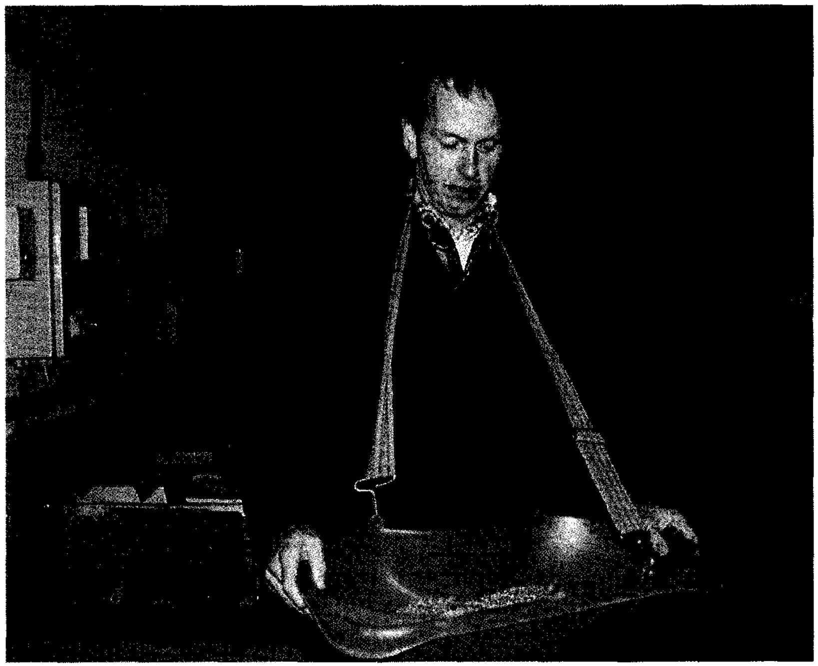


Photo courtesy J. S. Church

Figure 6.8 Providing inexpensive substrate for birds to peck at will occupy the birds and deter aggressive and feather pecking, and increases the attractiveness of the range area.

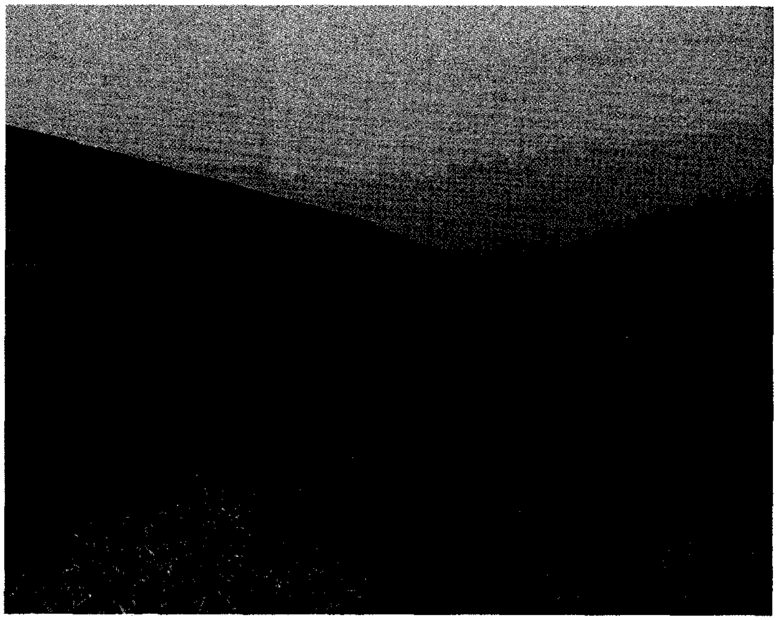


Photo courtesy J. S. Church

Figure 6.9 Alternating range access and ploughing is necessary to encourage pasture recovery, and maintain range attractiveness, and would benefit the range seen in this figure.

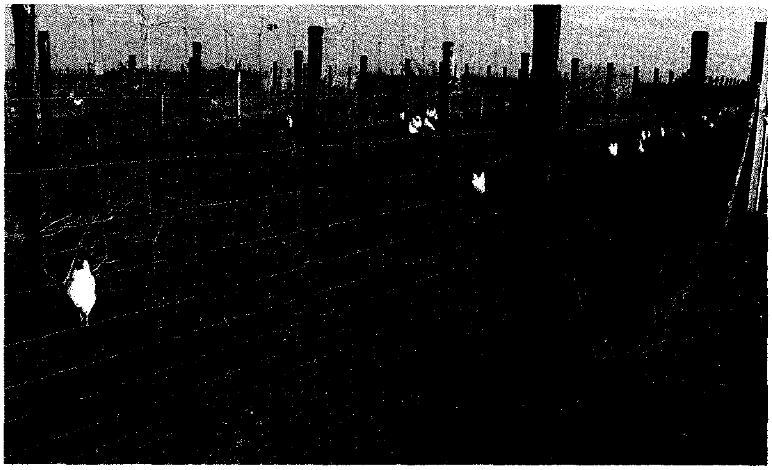


Photo courtesy J. S. Church

Figure 6.10 The Roundel (Adapted from Houden van Hennen, 2004)

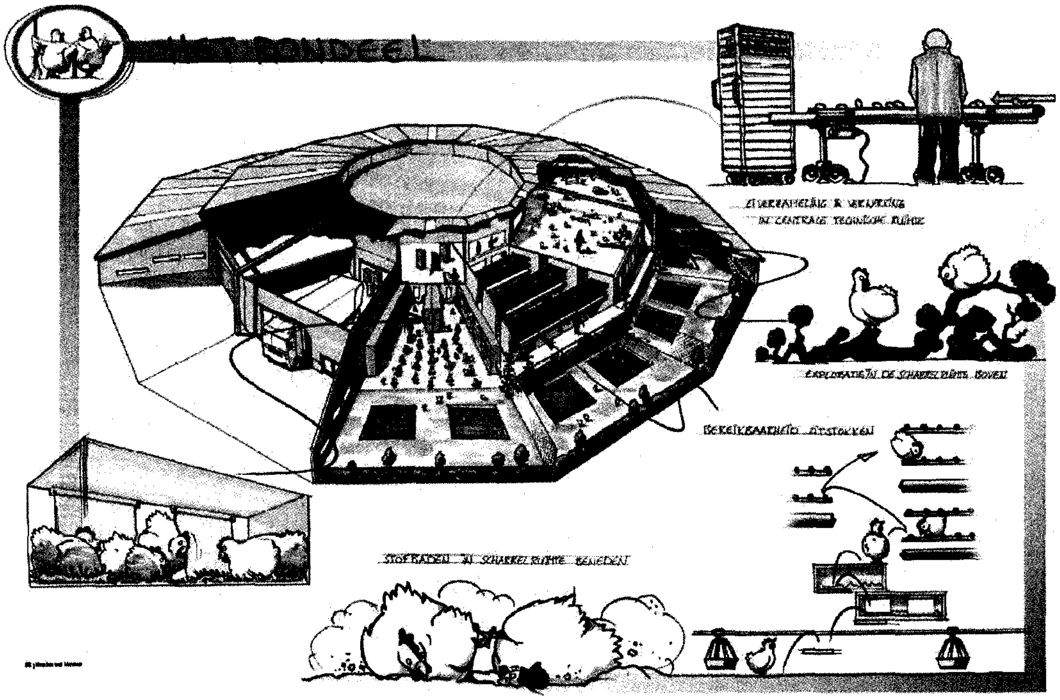
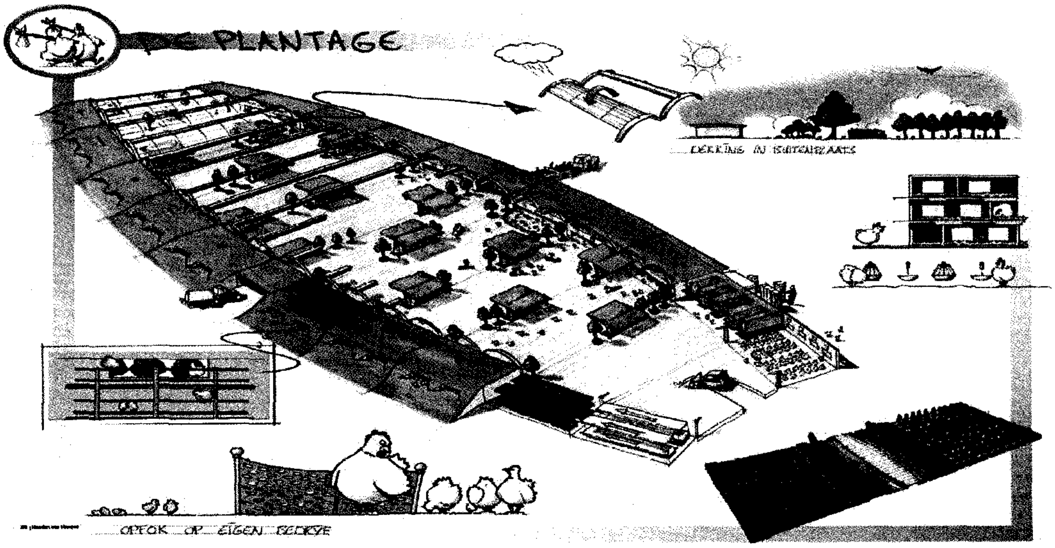


Figure 6.11 The Plantation (Adapted from Houden van Hennen, 2004)



6.4 Introduction to Switzerland

Switzerland is a small, mountainous country that encompasses an area of 41,285 square kilometres. The Swiss Plateau, a basin that extends across the nation, is flanked by two mountain ranges that occupy approximately 70% of Switzerland's land base. The plateau is approximately 50 kilometers wide, and contains fertile soils, and many lakes and rivers. Elevation in the Swiss Plateau region averages 400 m above sea level (Encarta, 2004b; Wikipedia, 2004b).

In 2004, the Swiss population was estimated at 7,450,867. The overall population density approximates 184 persons per square kilometre, however 90% of the population lives in the plateau region. Almost 70% of Swiss inhabitants are considered urban dwellers, yet the vast majority of people reside in small towns (Encarta, 2004b; Wikipedia, 2004b).

Switzerland's climate varies considerably as a result of extreme differences in land elevation, and variable exposure to wind and sun. The average annual temperature in the plateau region is approximately 10°C, ranging from 27°C in the summer to below freezing in the winter. Mountain range temperatures are significantly lower throughout the year. Annual precipitation averages 91 cm in the Swiss Plateau and can reach 260 cm in the mountains. Precipitation in the winter falls primarily in the form of snow (Encarta, 2004b; Wikipedia, 2004b).

In 2004, 4% of Swiss workers were employed in the agricultural, forestry and fishing sectors and approximately 11% of Switzerland's land was used for agricultural production. Switzerland's steep terrain, which limits agricultural expansion and cultivation, is primarily used for grazing pasture, and dairy production dominates the agricultural sector. Water is Switzerland's primary natural resource and approximately 30% of the land is forested (Encarta, 2004b).

Switzerland, a democratic nation, is governed at both federal and sub-national levels. The country is divided into 26 states known as cantons and with the exception of exclusive federal powers such as declaration of war and peace, and regulating the armed forces, treaties, alliances or trade, cantons exercise power of government. Swiss citizens widely influence legislation by electing representatives, challenging laws through referendums, and by introducing amendments to the federal constitution via popular initiatives (Encarta, 2004b; Wikipedia. 2004b). Public awareness and involvement in the democratic process is apparent from the impact the referendum has had on Swiss legislation. Over the last 120 years, more than 240 initiatives have been introduced, and have influenced numerous policies such as those relating to immigration, racial discrimination, women's rights, and animal welfare (Encarta, 2004b; Wikipedia, 2004b).

Swiss concern for environmental issues has resulted in the implementation of legislative policies regarding environmental protection, conservation and pollution management. Switzerland actively participates in national and international treaties aimed at reducing air pollution and production of hazardous waste, promoting biodiversity, and protecting endangered species (Encarta, 2004b).

Switzerland is a highly industrialized nation renown for excellence in academic, technical and vocational education, a strong work ethic, and efficient production of high quality goods. While the Swiss domestic market is limited and import costs generally exceed export earnings, income from services such as banking, insurance and tourism is substantial. Primary foreign trade partners include western European nations, the United States, Japan and China. Switzerland has one of the highest living standards worldwide (Encarta, 2004b).

Switzerland has maintained neutrality to preserve independence, and in doing so has become a preferred location for conducting international assemblies and establishing global organizations such as The International Red Cross and the UN. Switzerland is an active participant in international organizations such the World Trade Organization and the European Free Trade Association, and in 2002 became a member of the UN (Encarta, 2004b). While not currently a member of the EU, Switzerland has begun to adjust its legislative policies in accordance with EU regulations (Encarta, 2004b; Wikipedia, 2004b).

6.4.1 Swiss Egg Production

There are approximately 3 million laying hens in Switzerland (Fröhlich, 2004) and in 2003, Swiss hens produced 656 million eggs (GalloSuisse, 2004). Switzerland's 2003 per capita egg consumption, including processed egg product, was 183 eggs (GalloSuisse, 2004). Table egg production is more than 75% self sufficient in Switzerland (Fröhlich, 2004; GalloSuisse, 2004) and approximately 50% of eggs used for food processing are imported (GalloSuisse, 2004). Swiss consumers prefer brown-shelled eggs with a golden-yellow yolk (GalloSuisse, 2004).

In Switzerland, there are approximately 1000 laying hen producers and the average flock size is 3000 hens (Fröhlich, 2004). Swiss producers may sell their product as system eggs, either through trade associations, wholesale or retail trade channels. Alternatively, eggs can be directly marketed to consumers or purchased at the farm (GalloSuisse, 2004). Producers receive higher prices for direct-marketed eggs but are not eligible for the services provided by trade associations (Weidhof, 2004).

Over 75% of Swiss flocks are housed in aviary systems and no laying hens are kept in cages. Only 18% of flocks are limited to indoor access, 80% have access to wintergardens, and 12% of flocks have access to both wintergardens and free range areas. The remaining 2% of flocks are housed in free range systems (Fröhlich, 2004). In Switzerland, eggs must be labeled with a code representing the country of origin as well as a housing system number. Swiss eggs are identified by the letters CH, and with the exception of the number 3, housing codes follow the same guidelines used in the EU (0 - organic production; 1 - free range with outdoor access; 2 - floor systems). Since there are no cage systems in Switzerland, the number 3 represents imported eggs. Many farmers include the laying date and farm identification number on the eggs, to facilitate tracking (Fröhlich, 2004; GalloSuisse, 2004). Imported eggs that are produced in cage systems not authorized in Switzerland must be identified by a label on the carton that reads "Produced in cages not admissible in Switzerland" (GalloSuisse, 2004).

6.4.2 Swiss Salmonella Control Program

The Swiss Salmonella control program was first established in the late 1980's to regain consumer confidence in egg products. In response to worldwide concerns regarding Salmonella infection, Swiss egg consumption had declined from approximately 220 to 180 eggs per capita (Fröhlich, 2004).

The 1994 Swiss Zoonosis Order requires all cases of Salmonella infection in poultry to be reported, and suspected cases must be tested by an authorized veterinarian. Parent and layer flocks that test positive for Salmonella must be destroyed. Cleaning and disinfection practices must be repeated until the housing facility is confirmed negative for Salmonella contamination (Wilk et al., 2000).

Since all breeding flocks and some laying flocks are imported, Swiss Federal import regulations require stringent monitoring to prevent vertical transmission of Salmonella. Imported flocks are quarantined for 15 weeks and suspect flocks are serologically tested upon arrival. During the quarantine period, live chicks and box liners are tested on day 1, culled or dead chick samples are obtained at the end of weeks 1, 2 and 3, and faeces samples are tested at the end of weeks 5 and 6. For parent breeder flocks, faeces samples are tested weekly between the ages of 15 through 20 weeks, and fecal samples are collected every 8 weeks during egg production. For hatcheries, meconium and dead chicks in the shell must also be tested (Wilk et al, 2000).

A voluntary monitoring program has also been established for parent layer flocks and participation is approximately 95%. Culled and dead birds, fecal and blood samples, and drag swabs are regularly tested, to detect Salmonella infection before hens begin production. In the hatchery, meconium, eggshells and fluff are tested from every hatch (Wilk et al, 2000).

During the rearing period, chicks and box liners are tested on day 1 and all dead chicks, as well as culls and fecal samples are examined at weeks 1, 2 and 3. Fecal samples are obtained at weeks 5, 8, 12 and 15, and blood samples are tested when birds are 5, 15 and 22 weeks old. Additional fecal and blood samples are collected every 8 weeks during production. Bird dissections are also conducted for flocks exhibiting increased mortalities. At the hatchery, fluff, eggshell and meconium samples are tested from every hatch (Wilk et al., 2000).

Swiss producer who directly market their eggs to consumers must contract an accredited laboratory to conduct Salmonella testing (Weidhof, 2004). In Switzerland, costs associated with destruction of positive testing flocks are shared by the Swiss government and the European Commission (Wilk et al., 2000).

6.4.3 Welfare and Housing Legislation in Switzerland

6.4.3.1 Implementation of the Swiss Federal Act on Animal Protection

Prior to 1963, animal welfare policies in Switzerland were limited to prohibiting intentional cruelty to animals and requiring stunning before slaughter. In 1963, a proposal to create a comprehensive animal welfare article was submitted to the Swiss parliament by a veterinarian and a national councilor from the canton of Basel-Landschaft. The proposal however, which would have provided a foundation for a federal animal welfare act, was not considered (Studer, 2001).

In 1964, publication of Ruth Harrison's *Animal Machines* in the United Kingdom generated considerable public concern for the welfare of farmed animals. The British government responded by establishing a commission, the Brambell Committee, to evaluate welfare standards of agricultural species. The commission launched an independent Farm Animal Welfare Council (FAWC), whose concept of the Five Freedoms generated international awareness of livestock welfare (Appleby, 2004). The commission also passed an Agriculture Act that called for the development of minimum Codes of Recommendation for the Welfare of Livestock (Appleby et al., 2004). For laying hens, the codes recommended increasing the height and floor area of cages and limiting cage stocking densities, to allow birds to stand up and extend their wings (Studer, 2001).

In Switzerland, the concerns highlighted by the Brambell commission attracted considerable public attention to the concept of protecting farm animals from avoidable cruelty. Two separate parliamentary proposals to create a federal welfare act were submitted in 1969, and in spite of considerable interest from the cantons, Federal Council deferred, recommending that the cantons develop individual policies (Studer, 2001).

In response, in 1969 an Animal Welfare Act was initiated and approved by 85% of voters in the cantonal of Zurich. The Act was the first to require the appropriate keeping of animals as a measure of protection from cruelty. As a result, in 1971 a study was commissioned to prepare an animal welfare article as an amendment to the Constitution. The article included stipulations regarding animal keeping, transport, slaughter and experimentation, and in 1973 the amendment was approved by Parliament. Animal welfare regulations would thus be enacted at a federal level but would be implemented by the cantons (Studer, 2001).

A research commission was next required to draft an Animal Welfare Act. The commission proposed that keeping pigs and poultry in cages, housing calves on slatted floors and housing farm animals in darkness should be prohibited. In support of this proposal, the Swiss Farmer's Union also expressed concerns regarding the increasing dependence of Switzerland on feed imports, as a result of intensified farming. Considerable opposition to these views was expressed both by poultry producers and Migros, Switzerland's largest retail corporation. However, in response to corporate and industry resistance, a 1976 petition calling for the ban of battery cages was presented to Parliament by animal welfare organizations. The petition was supported by 400,000 signatures (Studer, 2001).

In 1977, the Federal Council submitted a bill to Parliament, outlining the ability of the Council to prohibit methods of keeping that were in opposition with animal welfare principles, particularly methods of cage housing and keeping animals in the dark. Public opposition to this apparent compromise caused Council to revise the bill, and in 1978 Parliament approved an Animal Welfare Act that included a ban on traditional cage keeping (Studer, 2001). The Swiss Federal Act on Animal Protection (APA) was officially approved by 81% of Swiss voters at the end of 1978 (Favre and Hall, 2002).

6.4.3.2 Overview of the Swiss Federal Act on Animal Protection and the Swiss Animal Welfare Ordinance

The APA clearly stipulated that unjustifiably exposing animals to pain, suffering, physical injury or fear is not tolerated, including pain, suffering or injury resulting from restricting freedom of movement (Swiss APA, 1978). According to the APA, The Federal Council determines requirements for animal keeping, and prohibits keeping that is inconsistent with animal welfare principles. This includes certain types of cage keeping which may be subject to authorization. A 10-year transitional period to coordinate existing facilities with these regulations was provided (Swiss APA, 1978).

To establish clear, measurable guidelines for the APA, the Federal Council issued an Animal Welfare Ordinance (AWO). When a draft version of the Ordinance was formulated in 1980, the public remained discontented and petitioned for additional space for animals, and greater freedom of movement and exercise (Studer, 2001). In May 1981 however, the Swiss AWO was instigated. In brief, the AWO stipulated that keeping arrangements for animals should not interfere with body functions or natural behaviours of the animal, and permanent tethering is prohibited. Enclosures must permit freedom of movement, access to daylight when possible, and provide minimum dimensions specified in the Ordinance. For laying hens, the Ordinance stipulates a minimum requirement of 800 square cm floor area per bird as well as protected nest areas, perches or grating (Swiss AWO, 1981). Under these minimum conditions, conventional battery cages have effectively been banned. Although furnished cage systems that could meet these requirements would be permitted if authorized, no such systems were, or have since been approved (Studer, 2001). Consequently, non-cage systems have prevailed in Switzerland.

The AWO further stipulates that all individuals involved in attending to animals must receive training at a recognized institution, to ensure basic knowledge of keeping and proper care of animals is imparted, and detailed instruction in a specified discipline is obtained (Swiss AWO, 1981). Education and training is necessary to minimize deficiencies in animal welfare resulting from a lack of knowledge (Wyss et al., 2004).

Beak clipping of chicks is permitted, provided the procedure is not performed to the extent that it interferes with the birds' ability to feed (Swiss AWO, 1981). The procedure is carried out at the hatchery and if performed correctly, allows normal use and wear of the beak such that re-trimming is not necessary (Figure 1). Behavioural manipulation devices such as electric wire and cow shock guards are not permitted in Switzerland (Fröhlich, 2004).

Flock size may not exceed 18,000 birds, including 12,000 hens and 6000 rearing pullets (Fröhlich, 2004; GalloSuisse, 2004). Access to wintergarden and outdoor range must be available between 1100 and 1700 h. Use of antibiotics is only permitted for therapeutic purposes and requires veterinary instruction. Animal proteins and antimicrobial stimulators may not be used in animal feed (GalloSuisse, 2004).

Egg washing is not permitted in Switzerland, and all dirty eggs must be processed (Fröhlich, 2004). Eggs that have not been refrigerated must be sold within 20 days after having been laid. After this period, saleable eggs must be refrigerated (GalloSuisse, 2004).

6.4.3.3 Authorization Procedure for Housing Systems and Equipment

Authorization by the Federal Council is required prior to the advertising or selling of mass-produced housing systems and equipment for cattle, sheep, goats, pigs, poultry and rabbits. Equipment includes feeding and watering systems, floor coverings and manure grids, and any barriers, fences or equipment, including tethering devices, designed to control the behaviour of the animal. Authorization is conducted by the Federal Veterinary Office (FVO) (Swiss AWO, 1981), and the procedure is carried out either by the Centre for Appropriate Keeping of Poultry and Rabbits, or The Centre for Proper Management of Ruminants and Pigs. Only systems or equipment in accordance with Swiss animal welfare legislation are authorized (Fröhlich, 2004; Wyss et al., 2004). Applications are submitted by the manufacturer along with blueprints, details regarding materials, construction design, and references (Studer, 2001). If possible, approval decisions are based upon past experience with similar equipment and scientific evidence from the literature. When practical testing is required due to concerns regarding the appropriateness of the equipment or lack of scientific literature or practical experience (Studer, 2001), physiological, behavioural and veterinary inspections are conducted to assess animal welfare (Fröhlich, 2004; Wyss et al., 2004).

Practical testing of new housing systems is conducted with at least 4 different flocks and staff. Flocks are assessed for external condition prior to entering and after leaving the systems to determine system impact (Studer, 2001). To assess behaviour, deviations or disturbances from the normal daily behavioural repertoire are considered for an entire day when the hens are 30 and 50 weeks of age. For laying hens, the normal behavioural functions include eating and drinking, oviposition, locomotion, resting, comfort, explorative and social behaviours (Fröhlich, 2004; Studer, 2001). Behavioural functions should correspond with the appropriate functional areas of the housing system and birds should not be subject to physical injury when performing normal functions. Hygiene, morbidity and mortality, as well as manageability, environmental quality, and lighting are also considered. Veterinary examinations are conducted for all ill or dead hens (Studer, 2001).

Authorizations granted by the FVO may be limited or contingent upon improvement of conditions. The authorization procedure serves to protect the welfare of the animals housed in the systems, as well as to minimize financial loss for producers and manufacturers (Studer, 2001).

6.4.3.4 Additional Roles of the Swiss Federal Veterinary Office

In addition to conducting the authorization of housing and equipment systems, the FVO is involved in preparing and enforcing legislation, training and educating veterinary officials, and providing advice to producers, animal transporters, slaughter facilities and veterinarians. The FVO also manages public relations and supports research and development (Wyss et al., 2004). The Centre for Appropriate Keeping of Poultry and Rabbits, and the Centre for Proper Management of Ruminants and Pigs both collaborate with universities in conducting research regarding developing housing designs and assessing animal welfare in various housing systems. Knowledge is relayed to producers and veterinary officials through formal education, advanced courses or by providing information as required (Fröhlich, 2004; Wyss et al., 2004). The FVO is also responsible for preparing courses and educating the supervisory bodies responsible for conducting on farm assessments, to ensure housing systems are in accordance with Swiss legislation (Wyss et al., 2004). FVO representatives also contribute to international committees relating to animal protection and the Council of Europe (Fröhlich, 2004).

6.4.4 Incentive for Change to Alternative Housing Systems in Switzerland

Implementation of an agricultural policy that promotes production in welfare-conducive housing systems was clearly the most significant contributing factor in the transition to alternative housing for laying hens (Wyss et al., 2004). The Swiss APA and AWO provide clear guidelines for producers to follow, and specify allowable equipment and housing types through the authorization procedure. Appropriate systems are made available through research and development. Minimizing stocking numbers encouraged the transition from more intensive production systems, and provision of a transition period enabled producers to gain experience and adjust to the changes (Swiss APA, 1978; Swiss AWO, 1981). Teaching and education systems have provided knowledge of proper animal keeping, and surveillance, monitoring and enforcement have further ensured compliance with the legislation (Wyss et al., 2004).

The Swiss government is now also providing economic incentive in the form of eco-payments for producers who provide hens with access to free range or wintergardens.

To be eligible, producers must comply with specific guidelines (Fröhlich, 2004; Studer, 2001). As a result, over 80% of Swiss flocks today have access to outdoor systems (Fröhlich, 2004).

Public and societal group awareness for animal welfare, involvement in the legislative process and pressure to enforce change were also instrumental in encouraging the transition. Consumers continue to support Swiss egg production, and willingly pay higher prices for eggs that are produced in non-cage and outdoor access systems (Studer, 2001).

Producer willingness to attempt production in new systems, fulfill the requirements of the AWO within the transition period, and comply with the inspection and authorization procedures was essential for a successful transition to alternative systems (Fröhlich, 2004; Studer, 2001). The progressive approach adopted by producers has fostered innovative system developments and managing strategies, and has instilled pride in production. Some producers have developed websites of their facilities to advertise the welfare-friendly keeping practices they have adopted. Two such examples can be found at www.rieder-eier.ch/ and www.gefluegelhof.ch/.

Despite their initial opposition to alternative housing systems, retailers have also helped to foster the transition. In 1987, Migros and COOP, Switzerland's two largest retail corporations announced to producers that as of 1989, they would no longer purchase eggs from battery housed hens. The retailers wanted to project a new image associated with premium, welfare friendly products, and in the process would profit from higher priced eggs. Since these corporations supplied eggs to approximately 70% of consumers, producers were strongly motivated to change housing systems (Fröhlich, 2004; Studer, 2001).

Waro, another retail supermarket, next decided to ban the sale of imported table eggs, since these were generally produced in battery cages. Migros and COOP followed suit in 1992. Imported eggs are still sold as processed product or as ingredients in other goods. However Migros and COOP no longer sell pasta made with eggs from caged hens, and both companies produce products such as mayonnaise with eggs from cage-free hens. Furthermore, both retailers support free range and wintergarden systems since profit margins from these eggs are higher (Studer, 2001).

GalloSuisse, the Swiss Association of Egg Producers has also facilitated the conversion from battery housing to non-cage systems by increasing the demand for Swiss eggs. The Association continues to campaign to promote Swiss egg quality. GalloSuisse highlights the mandatory requirements followed by Swiss egg producers and the assurance that Swiss eggs are produced by hens kept in respectable housing systems. Maximum permissible hen numbers are advertised as precluding intensive, industrial production, which benefits the environment, and hen health and feed regulations are associated with quality of Swiss egg production. The Association also reminds consumers that unlike imported eggs, Switzerland's eggs are fresher, and shipping routes are short and therefore ecologically friendly (GalloSuisse, 2004).

The Association also provided direct support for producers during the transition to non-cage systems by organizing tours of alternative facilities and training sessions (Studer, 2001). In 1991, just prior to the end of the transition period when almost all egg producers had converted to non-cage systems, the Association strongly urged the remaining facilities and cantonal authorities to finalize the conversion. By completing the conversion before the end of the transition period, the Swiss egg producers promoted a very positive image of their industry (Fröhlich, 2004; Studer, 2001).

6.4.5 The Swiss Experience with Aviaries

During the transition to non-cage systems, domestic egg production remained stable in Switzerland (Wyss et al., 2004). This can be attributed in part to the gradual change over a 10-year period. However, it is clear that since aviaries provide hens with access to the third dimension of the barn, stocking densities are very similar to densities in battery cages, and production in an aviary system therefore does differ considerably (Studer, 2001). Wyss et al. (2004) suggest that production in aviaries can be equally profitable for producers as production in cages, provided the eggs are sold for a higher price.

Fröhlich (2004) has found that well managed aviaries are superior to deep litter systems. Aviaries allow a higher stocking density than litter systems, housing 12.5 birds per square meter and 7 hens per square meter, respectively, and birds are less likely to crowd in corners and crush other birds. Feather pecking is typically not problematic in Swiss aviary systems (Fröhlich, 2004; Weidhof, 2004).

The first aviary system to incorporate separate functional areas for eating, drinking, oviposition, scratching/bathing, walking, resting and flying, was designed by Swiss researchers in the 1970's (Studer, 2001). Today, the most common aviary system in Switzerland is the Natura system, produced by Inauen (Big Dutchman). Separate functional areas are located on three levels, and the system has integrated nests and is equipped with manure belts (Studer, 2001).

6.4.6 Management strategies

Swiss producers and researchers agree that dedicated management is essential for successful production in loose housing systems such as aviaries (Fröhlich, 2004; Weidhof, 2004). Unlike battery cages, where the repertoire of hen activity is limited, aviary systems are dynamic and many aspects require careful monitoring. Good management strategies will contribute to flock calmness, which is essential for day-to-day activity, as well as when changes or novelties are introduced (Fröhlich, 2004).

6.4.6.1 Housing Layout and Division, and Natural Vertical Tendencies

Aviary systems must be structured, providing separate areas for separate functions. This will minimize hen disturbance, thereby reducing frustration and aggression (Fröhlich, 2004). Safe, quiet places such as raised perches and nesting sites should be provided for hens to adequately rest, nest and escape from aggressors (Figure 2). Designs should also provide "traffic trails", or roadways that allow birds to move between tiers, or from one part of the system to another, without disturbing the activities of other birds (Fröhlich, 2004).

Perches are best situated at the top of the system since birds will naturally roost at height, where they are at less risk from predation. Perches, step systems and bridges can be placed to facilitate movement between systems (Figure 3). Minimizing the distance between nest and system tiers to 1 m will also facilitate movement, especially for brown birds, who tend to be somewhat less energetic (Fröhlich, 2004; Weidhof, 2004).

Brown hens may also be more inclined to follow producers, which may lead to crowding and crushing, particularly at the end of the barn. Barns should therefore be divided into multiple sections. Most flocks are divided into groups of 3000 or 4000 hens (Fröhlich, 2004; Weidhof, 2004).

6.4.6.2 Nest Use

Birds should be moved from the rearing system to the laying facility approximately 1-2 weeks prior to onset of lay, to familiarize hens with the nest boxes before they begin to oviposit. (Fröhlich, 2004; Weidhof, 2004). Group nests should be approximately 50-60 cm deep and approximately 80 cm long. Nest boxes that are too deep will become overcrowded and may cause birds to overheat. Nest boxes that are too long will invite activities other than nesting, including aggressive interactions (Fröhlich, 2004). In aviary systems, nest sites should be closed at night since birds become inclined to overnight in the nest boxes, as they age (Fröhlich, 2004; Weidhof, 2004).

Changing the light intensity over the course of the day may increase nest box use (Weidhof, 2004). Bright lighting in the morning will increase bird activity and encourage entry into the nest box. Light intensity should be reduced again after midday (Weidhof, 2004).

Attaching metal dividers to the nest boxes may discourage hens from crowding end nest boxes. Dividers appear to create the illusion that all nest sites are end boxes, and hens more readily use nest facilities along the length of the barn when dividers are present (Figure 4). Distributing birds across the system helps to reduce floor egg laying and improve egg quality (Weidhof, 2004).

6.4.6.3 Air Quality

Foraging and dust bathing activity cause rotation of the litter which encourages drying. While this will improve ammonia levels, litter that is too dry will increase the amount of dust in the barn. Limiting the amount of litter to a level that enables hens to scratch at the concrete will satisfy hen requirements for foraging and bathing, and minimize ammonia and dust levels (Figure 5) (Fröhlich, 2004; Weidhof, 2004). Litter should be renewed at least once during the production cycle and spreading straw regularly will encourage bird activity, and hence litter drying. Cleaning manure belts frequently and a good ventilation system will ensure ammonia emissions are minimized (Weidhof, 2004).

6.4.6.4 Production

Rearing birds in an environment that resembles the production facility is important to facilitate the transition between systems, and to encourage development of foraging and litter pecking. Pecking directed at the ground will minimize feather and aggressive pecking, thereby maintaining plumage condition and minimizing wounds (Fröhlich, 2004).

Producers should also increase the attractiveness of the litter, to direct pecking behaviour at the ground. According to Fröhlich (2004), researchers at the University of Munich have observed that very active birds are more likely to feather peck than less active birds. Therefore, preoccupying such birds would be beneficial in preventing feather pecking. Spreading wood shavings and straw, providing long or hatched straw in blocks, and supplying limestone blocks all promote litter pecking (Fröhlich, 2004; Weidhof, 2004).

Red mite populations will emerge regardless of whether wood, steel or plastic perches are installed in a system. Infestations are best controlled by ensuring manure is removed often, and by maintaining hygiene and a lower temperature in the barn (Fröhlich, 2004).

Fröhlich (2004) has observed that the incidence of bumblefoot is higher for perch shapes where the palm of the foot is in contact with the perch, since moisture is trapped. Wire perches and I-shaped roosts appear to avoid this problem since the palm of the foot is exposed. Fröhlich (2004) suggests that foot condition may also be influenced by perch temperature. Metal perches, for example tend to be colder and appear to cause more foot problems.

Feed consumption can be improved by running feed systems frequently over the course of the day. Running feed belts 8 or more times will reduce crowding at feeders and encourage subordinate birds to feed, thereby improving flock uniformity. Providing less feed more often also reduces feed wastage (Weidhof, 2004).

6.4.6.5 Outdoors: wintergarden and free range

Providing wintergarden (Figure 6) and free range areas on both sides of the barn allows producers to alternate access to range systems, to accommodate weather conditions and allow for pasture recovery (Fröhlich, 2004; Weidhof, 2004). Pasture condition can be further improved by increasing the attractiveness of the range area. Providing protective covering such as trees, shrubs and long grasses will encourage birds to move away from the barn and explore their range. This will minimize resource depletion and saturation of the soil with fecal contaminants. Protective covering will also serve as a windbreak and encourage ranging at colder temperatures (Fröhlich, 2004).

6.4.6.6 Finding the Right Bird

Swiss producers and researchers have observed that medium-sized, white-feathered breeds such as Lohman Select and Lohman Tradition are very suitable to aviary and range systems (Fröhlich, 2004; Weidhof, 2004). White feathered strains appear to be less aggressive and much calmer than brown hens, and fewer flocks require beak trimming. Medium-sized breeds are also better suited to floor and outdoor range systems than light hybrids (Fröhlich, 2004; Weidhof, 2004). Brown hens tend to be less explorative than white-feathered strains and prefer to use lower level amenities in the system. Mixing white and brown strains may help to distribute the bird population and thereby maximize use of space (Weidhof, 2004). Brown egg laying strains such as Lohman Brown and Lohman Silver birds are generally quite calm and perform well in aviary systems (Fröhlich, 2004).

6.4.7 Summary and Conclusions

Switzerland is a small, mountainous country with a limited land base for production of domestic goods. Nonetheless, through excellence in education, a strong work ethic and high standards of production, Switzerland has established a reputation for high quality, efficient production of goods and services, and has thereby secured access to domestic and global markets.

Public awareness and involvement in the Swiss democratic process have had a significant impact on issues relating to equality, environmental concerns, international policy, and animal welfare. Increasing concern for the well being of domestic animals prompted Swiss citizens to lobby governmental implementation of the 1979 Swiss Animal Protection Act and 1981 Animal Welfare Ordinance. Together, these policies provide comprehensive, clear and measurable guidelines concerning the protection of animal species.

To prevent unjustifiable exposure to pain, injury or suffering, the Swiss Animal Protection Act and Welfare Ordinance require all housing systems and equipment to be authorized by federal authorities. Housing systems and equipment may not interfere with the natural behaviour or freedom of movement of domestic animals, and systems are evaluated and tested in practice before receiving approval for commercial sale. Minimum requirements for laying hen housing facilities have resulted in an effective ban of conventional cage systems and to date, no enriched caged environments have been approved. Aviary systems, which permit high stocking densities yet provide hens with an environment conducive to their natural behaviour, have emerged as the preferred hen housing system in Switzerland.

The successful transition to non-cage housing systems in Switzerland can be attributed to the involvement of many different sectors. The Swiss government, in addition to legislating a ban of traditional cage systems, permitted a 10-year transition period for producers to adjust to new housing systems. The government has also provided economic incentive, in the form of eco-payments, to encourage producers to develop wintergarden and free range access areas. Swiss consumers fostered the transition by supporting domestic egg production, rather than purchasing less expensive, cage-derived foreign eggs. The willingness of Swiss producers to change past methods of production in favour of more welfare-conducive systems, and the progressive approach adopted by farmers, facilitated the transition, encouraged innovative developments and established a positive reputation for the industry. Retailers supported producers who converted housing systems by discontinuing the sale of eggs from caged hens and imported eggs. Finally, the Swiss Egg Producers Association widely campaigned to promote the quality and animal-friendly aspects of Swiss egg products, thereby increasing domestic demand for eggs produced in Switzerland.

Since converting to non-cage housing systems, producers and researchers in Switzerland have developed considerable experience in managing alternative housing environments. Both offer valuable suggestions regarding housing design, and improving use of facilities, air quality, production and management of outdoor range areas.

The Swiss progressive approach to implementing housing systems that protect the welfare of farmed animals is admirable, and provides evidence that alternative laying hen production can be highly successful. The strategies adopted to protect and promote domestic production will prove invaluable for other industries willing to change.

6.4.8 Figures

Figure 6.12 A beak clipped Swiss hen. When correctly performed, beak clipping does not interfere with feeding and allows normal wear and use of the beak.

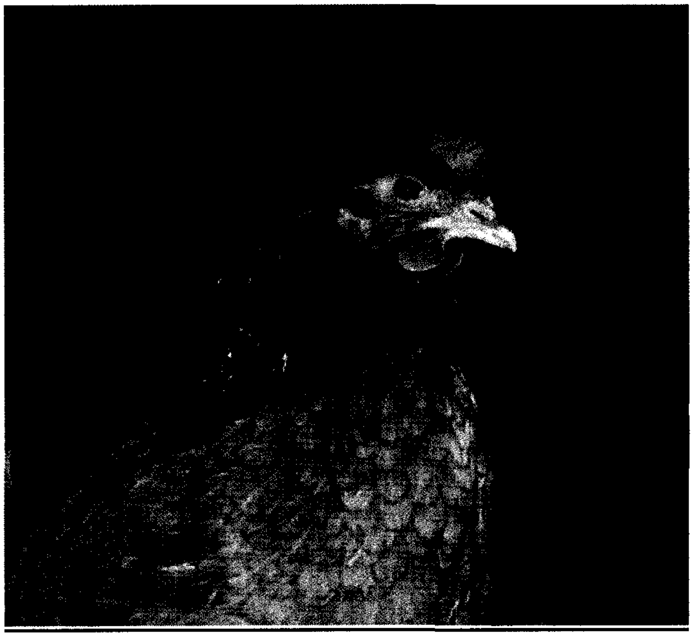


Photo courtesy J. S. Church

Figure 6.13 Barn layout should provide separate areas for separate functions, such as perching areas or these nesting sites.

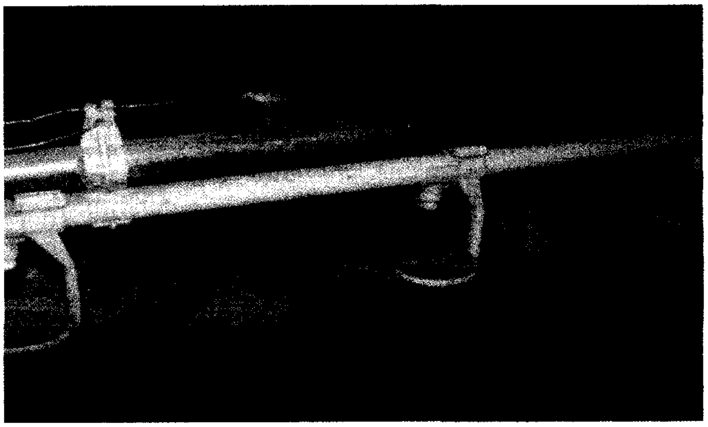


Photo courtesy J. S. Church

Figure 6.14 Perches, step systems and bridges can be placed to facilitate movement between systems and tiers, thereby encouraging natural vertical tendencies.

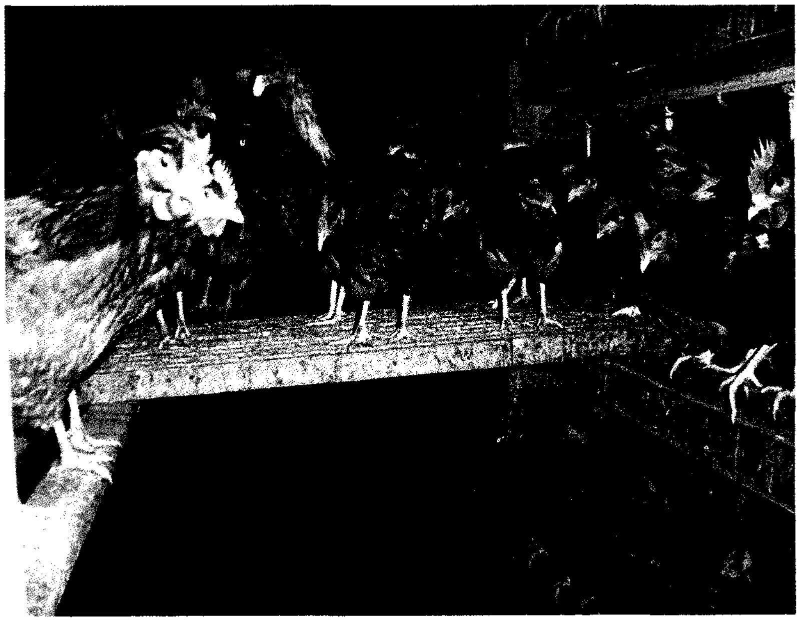


Photo courtesy J. S. Church

Figure 6.15 Metal dividers attached to nest boxes encourage bird distribution and use of nest boxes along the length of the barn, thereby discouraging floor laying.

Photo courtesy J. S. Church

Figure 6.16 To encourage litter drying and improve air quality, litter depth should be minimized to a level that allows hen to scratch the concrete floor.

Photo courtesy J. S. Church

Figure 6.17 Swiss wintergarden facility where birds can access feed, water and perches while ranging in a protected area.

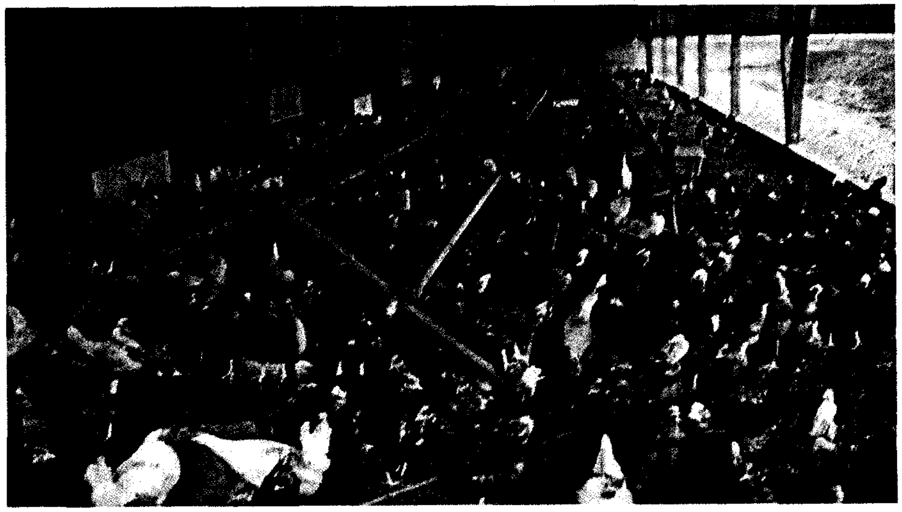


Photo courtesy J. S. Church

6.5 Introduction to Sweden

Sweden is a long and narrow country with a total area of 449,964 square kilometres. It is smaller than the province of Alberta (land area 661,848 square kilometres, (Statistics Canada, 2005)) but is the third largest country in Europe (Källander, 2002; Encarta, 2005). In 2004, the Swedish population was estimated at 8,986,400 and the overall population density approached 22 persons per square kilometre. Approximately 83% of the inhabitants are considered urban dwellers, and the majority of the population resides in the southern regions (Encarta, 2005).

The climate in Sweden can differ considerably between the north and south but is surprisingly moderate given the latitude at which the country is located. Summer temperatures range from 12° to 21°C, while winter temperatures range between -4° to 1°C in the south, and -14° to -6°C in the north (Källander, 2002; Encarta, 2005). Although the growing season in the south is nearly 100 days longer than in northern Sweden, the growing period in the north is intensified by long days and the midnight sun. Precipitation, which is highest in the mountain ranges and in the southwest, averages 790 mm annually in the south. Central and northern Sweden receive heavy snowfall (Encarta, 2005).

Agriculture is generally concentrated in Sweden's fertile lowlands. Since the majority of the land in Sweden consists of forests, mountains, lakes and marshlands, only 7% (~2.8 million hectares) of the total land area is cultivated. Nevertheless, Sweden's agricultural production is virtually self-sufficient (Källander, 2002; Encarta, 2005).

The majority of Swedish farms are family owned and operated, and the number of large farms is decreasing. Part-time farming is becoming increasingly popular in Sweden and since many farms own forested land, agriculture is often combined with forestry (Källander, 2002; Sweden, 2004; Encarta, 2005). In 2002, only 1.4% of the Swedish labour force was employed in the agricultural sector and over 60% of farmers were older than 50 years of age (Sweden, 2004).

Sweden's political system is a parliamentary democracy whose cabinet executive power is composed of a prime minister, department ministers, and non-specialized ministers. The country is divided into 21 functionally independent counties and 286 municipalities. Council members are elected by popular vote (Encarta, 2005).

The Swedish culture reflects a modern attitude that is sensitive to emerging issues, flexible to change, strives for efficient production and promotes animal welfare and environmental concerns. This is apparent in the Swedish proactive and sustainable approach towards farming. Over the last decade, for example, pesticide use has been significantly reduced, and efforts have been directed at decreasing ammonia, phosphorus and nitrogen leaching, resulting from agricultural activity. On January 1, 1995, Sweden joined the EU and in doing so, also became a member of the CAP (Sweden, 2004). EU direct support programs have influenced economic development in Swedish agriculture and have encouraged sustainable practices to continue. For example, environmental subsidies, of which the EU contributes approximately 50% of the funding, are available for producers who promote preservation of biological diversity, natural environments, and ecologically and socially sustainable agriculture (Sweden, 2004).

The Swedish proactive attitude has also been instrumental in promoting an image of organic farming as an environmentally sound means of achieving future requirements for high quality food products. The concept of organic farming was first introduced into the Swedish national agricultural policy in 1989 when the agricultural minister proposed the creation of a support program for farmers, a chair of organic production at the Agricultural University, and positions for three regional organic advisors. By 1993, a target of 10% organic production for the year 2000 was implemented by Parliament. Since joining the EU, Sweden has increased its organic cultivation to 14% of arable land, and has set a new target of 20% organic production by the end of 2005 (Källander, 2002; Sweden, 2004). Growth in organic farming is largely attributable to the agricultural policy and support programs, however, sustainable organic production is further ensured by industry federations that deal specifically with analyzing problems, developing marketing strategies, certification, providing producers with access to competent advice and knowledge, and informing consumers to establish awareness and trust (Källander, 2002).

Foreign relations and global concerns are also very important to Sweden. In addition to being a member of the EFTA and the WTO, Sweden is also involved in international treaties concerning issues such as pollution, biodiversity, climate change, ecological preservation and endangered species. Sweden's chief import and export markets include Germany, the United Kingdom, Norway, the United States, Denmark, Finland and France (Encarta, 2005).

6.5.1 Swedish Egg Production

Swedish commercial egg production is, for the most part, managed by large enterprise (SVA, 2005) where facilities range from 20,000 to 25,000 hens (Tauson, 2004a). In 2004, the Swedish laying hen population was approximately 5 million birds (Tauson, 2003; Encarta, 2005). More than 85% of Swedish hens are Single Combed White Leghorns (SCWL) (Tauson, 2003) and white eggs are preferred by consumers (Tauson, 2004a). Swedish yearly egg consumption approaches 200 eggs per person (Carlström, 2004).

In Sweden, approximately 92% of all egg production occurs in alternative housing systems. Sweden is the first country to adopt furnished cage housing for commercial production and today, approximately 40% of the hen population, or 2 million birds, are housed in furnished cages (Tauson, 2003). The majority of hens are kept in multi-tiered aviary systems or deep litter systems (Tauson, 2004a). Approximately 8% of production still occurs in conventional cages. Although Swedish legislation prohibits conventional housing, a small group of producers who were opposed to this ban fought in a local court to continue conventional keeping, arguing that the Swedish legislation had not been properly formalized in Brussels (Carlström, 2004; Tauson, 2004a). The producers won the right to continue conventional production until the EU cage ban becomes effective in 2012, however Swedish egg prices and market demand for eggs produced in more welfare-conducive housing systems are expected to encourage change to 100%

alternative production before then (Carlström, 2004). Alternative producers who complied with the Swedish legislation, invested in non-cage and furnished cage units, and incurred the expenses involved in the changeover, would prefer that the EU Directive ban of traditional cages be fulfilled (Eggs Sweden, 2004), and are also opposed to the possibility of an extension of the EU ban to accommodate new EU members (Tauson, 2004a).

As a member of the EU, Sweden follows the egg labeling system proposed by EU guidelines. Although enriched cage eggs are labeled as category 3 eggs, representing caged hens, packaging may specify that eggs were produced in enriched units (Tauson, 2004a). Packing stations also offer a higher price for eggs from enriched cages than eggs from traditional cages (Eggs Sweden, 2004). Producer prices are highest for organic eggs, followed by eggs produced in non-cage systems, enriched cages and traditional cages (Figure 1) (Eggs Sweden, 2004).

Swedish egg production was approximately 83% self sufficient in 2003. Swedish egg export is minimal, and imports are limited by high standards for Salmonella testing (Eggs Sweden, 2004). When Sweden joined the EU in 1995, the Swedish government stipulated that poultry, egg and meat imports into Sweden must be tested for Salmonella by the country wishing to export these products. Since few countries, with the exception of Finland and Norway, enforce levels of Salmonella control comparable to Swedish standards, the Swedish egg industry has been protected from an influx of egg imports, particularly less expensive imports from nations where hens are housed in conventional cage systems (Open Agriculture, 2004; Tauson, 2004a).

6.5.2 Swedish Salmonella Control Program

Development of an extensive program to eradicate Salmonella from the food chain was initiated in 1953 after 100 people in Alvesta died from an infection originating from an abattoir (Open Agriculture, 2004). The program, which was implemented by 1961, included monitoring of cattle, pigs, poultry meat and eggs. Voluntary testing of layer flocks during production and at slaughter became mandatory in 1994 (Wierup et al., 1995), and in 1995, Swedish testing practices were approved by EU requirements (95/50/EC) (SVA, 2004). Today, the prevalence of Salmonella is less than 1% in Sweden and of those cases reported, less than 15% are of domestic origin (Open Agriculture, 2004).

The Swedish Salmonella control program is guided by a principle of non-acceptance of Salmonella contamination, and for birds, is implemented through five standards (Open Agriculture, 2004; SJV, 2005; SVA, 2004):

1. A clean start: day old stock chicks must be Salmonella-free.
2. A clean environment: a high level of cleanliness, sanitation and rodent control must be maintained.
3. Clean water and feed: strict monitoring of feed and water is required to ensure these sources are free from Salmonella contamination.
4. A clean production chain: the entire production chain is routinely monitored and samples are tested by the program and by the national board of agriculture.
5. Immediate action strategy: upon detection, the whole flock must be destroyed, manure must be composted and houses must be thoroughly cleaned and disinfected.

Since Salmonella can be transmitted from parents to offspring through the egg, a fundamental strategy in controlling infection is to ensure that breeding flocks remain Salmonella-free (Breytenbach, 2004). Broiler breeder and layer breeding flocks are not maintained in Sweden, but are imported as day-old grandparents. To prevent infection from breeder sources, Swedish law not only requires that all fecal and microbiological sampling of imported breeding flocks is carried out in accordance with the Council Directive 92/117/EEC, but also requires additional sampling periods for grand chicks (SVA, 2004). Official certification is also needed as confirmation that day-old genetic stocks originate from Salmonella-free parents (Wierup et al., 1995).

Upon arrival in Sweden, floor covers from transport containers and pooled chick cloacal swabs are tested for all Salmonella serotypes. Liver, yolk sac and caecum samples are tested from all dead chicks. Grand chicks are quarantined for 15 weeks, and fecal, liver and caecum samples from dead or culled animals are bacteriologically tested at 1-2 weeks, 3-5 weeks, 9-11 weeks and again at 13 weeks of age. Detection of any Salmonella serotype in these genetic stocks requires flock destruction (SVA, 2004; Wierup et al., 1995).

During the rearing period, fecal, liver and caecal samples from parent generation stock are tested at 2-3 weeks, 6-8 weeks, and two weeks before transport to production systems (Wierup et al., 1995). Monthly fecal and tissue testing are compulsory during egg production and also serve to supplement hatchery sampling. In the hatchery, monthly samples of dust, eggshells and dead-in-the-shell chicks are tested, and every third month, samples are taken from the hatchery floors, walls and brooders (SVA, 2004; Wierup et al., 1995).

For laying hens, rearing fecal samples are collected at 2-3 weeks, and 2 weeks before transport to production facilities. During the laying period, fecal sampling is carried out at 25-30 weeks, 55-60 weeks and again 2-4 weeks before slaughter. In addition to the fecal samples collected from all grandparent, parent and layer flocks 2-4 weeks prior to slaughter, neck skin samples are obtained at the slaughter facility. Salmonella isolates found in neck skin samples are regarded as contamination at the slaughter site (SVA, 2004; Wierup et al., 1995).

Neither vaccination nor the use of antimicrobial drugs is permitted to prevent Salmonella infection in Swedish poultry (Breytenbach, 2004; SVA, 2004). Treatment of disease with antibiotics may reduce mortality and clinical symptoms but will not eradicate infection from the flock since birds that recover will continue to be carriers (Breytenbach, 2004). Consequently, in Sweden, every flock that is infected with Salmonella is destroyed, irrespective of serotype. All findings of Salmonella must be reported and tested for sero- and phagetype, as well as antibiotic resistance (SVA, 2004;

Wierup et al., 1995). Infected farms are placed under restriction and must be cleaned and disinfected. Feedstuff is destroyed or sterilized, and the feed supplier must also be tested, in order to trace the source of infection (SVA, 2004).

Sampling of feedstuffs follows legislative guidelines and is supervised by the Swedish Board of Agriculture (SJV). Both compulsory and voluntary sampling is performed and samples must be analyzed at an accredited laboratory. All positive findings are confirmed and serotyped by the SVA. The SVA also analyzes samples taken by official feed inspectors and Hygiene Groups, a panel comprised of an official feed inspector and the county veterinarian (SVA, 2004).

Compulsory feed mill sampling is carried out in accordance with HACCP guidelines. Mills that produce poultry feed are required to obtain a minimum of five samples per week from designated critical control points whereas those that produce feed for horses, ruminants and swine are only required to sample twice per week. Official feed inspectors obtain additional samples from critical points one to five times each year, as determined by the quantity of feed produced at the mill. Yearly inspections are also performed by Hygiene Groups at mills whose annual production exceeds 1000 tons of feedstuff. Samples are taken from such critical control points as aspirators, silo and feedstuff elevators, and areas surrounding pellet coolers. Producers may voluntarily obtain additional samples (SVA, 2004).

Feed materials differ in the risk they pose for exposing livestock to Salmonella infection and are classified as:

S1: having originated from an animal source
S2: having originated from a high risk vegetable source such as soy bean meal and some rape seed derived products
S3: having originated from a low risk vegetable source such as rice.

Sampling of S1 category feed must follow EU regulations (EC 1774/2002). A hygiene program that includes routine Salmonella sampling must be implemented for production of all feed material and must be approved by the SJV. All imported S1, S2 and S3 feed materials must be tested. If sampling is performed in the country of origin, proof of sampling is required. Feed testing positive for Salmonella is re-tested, decontaminated and is then either returned to source country or destroyed (SVA, 2004).

To minimize the risk of Salmonella contamination from feed, producers are advised to avoid using S1 feed sources, and are encouraged to provide pelleted sources obtained from reputable suppliers (SVA, 2004). In poultry production, rearing hens are only fed heat-treated feed sources. This trend is becoming more common during the laying period as well (Wierup et al., 1995).

Compensation for destruction of Salmonella-contaminated flocks varies with respect to flock type and participation in the voluntary Salmonella prevention control program. Owners of breeding flocks receive full compensation, paid in equal parts by the Swedish government and the EU. Layer producers who have adhered to the voluntary prevention program are reimbursed for 70% of their costs by the Swedish government, and an additional 20% through private insurance benefits. Owners who do not participate in the voluntary program are only entitled to 50% reimbursement through government funding. Insurance premiums for the latter producers are also higher (Gustafsson, 2005). Voluntary programs, which are generally determined by producer associations and authorities, are concerned with essential components of Salmonella control that rely on producer cooperation. Some examples include cleaning and disinfection, biosecurity measures, building maintenance, rodent control, and sampling (ICFI, 2004). Until 1984, 90% of the costs of destruction of poultry meat flocks were financed by the state. Since then, reimbursement has been provided by insurance companies, provided the chickens are sourced from breeder flocks and hatcheries that participate in the voluntary Salmonella control program (SPMA, 2004).

The increasing incidence of human Salmonella infection due to contaminated meat and egg products has also prompted the induction of more stringent control programs in other European countries. Denmark for example has successfully established eradication programs for broiler and layer flocks, and is the first country to introduce a "from feed-to-food" nationwide Salmonella control program in pork (Wegener et al., 2003). The strategies involve intensive and continuous serologic and bacteriologic testing of blood, fecal matter, product and environment and are described in detail by Wegener et al. (2003). A program to reduce the incidence of Campylobacter contamination of meat sources below the current level of approximately 10% has also recently been developed by the Swedish Poultry Meat Association (Open Agriculture, 2004).

6.5.3 Welfare and Housing Legislation in Sweden

The Swedish approach towards animal welfare reflects awareness and concern and is apparent in the high standards set by Swedish legislation. The AWA and AWO provide comprehensive guidelines that ensure proper care for domestic animals, promote health and permit the expression of natural behaviours (SFS, 2003; Sweden, 2004). In addition, the AWO provides a detailed description of the provisions required for the keeping of and caring for animals, and delegates which governmental agency will communicate these provisions (SAWA, 2004). Sweden also enforces strict monitoring programs to ensure compliance with legislative policies (Open Agriculture, 2004) and it is the responsibility of the SAWA to ensure that the AWA is uniformly enforced throughout Sweden (SAWA, 2004).

The Swedish movement towards a more stringent and comprehensive animal welfare act was largely influenced by Astrid Lindgren, author of the children's novels Pippi Longstocking and Michel. Lindgren was very well known and admired in Sweden and spoke publicly about her concerns regarding intensive agricultural systems (Carlström, 2004). Her objections to intensive farming raised awareness and profoundly influenced the Swedish people and in 1988, the government responded to public dissatisfaction by implementing a new animal welfare act and ordinance. The AWA and AWO specified that by 1994, all cages for layer hens would be required to include a perch and claw abrasive device (Appleby, 2003). These stipulations were largely based upon the recommendations of Ragnar Tauson, a Swedish poultry housing researcher who had investigated injuries to caged hens and improvements to cage design (Tauson, 1985; 1986; Appleby, 2003). The Act also stipulated that beak trimming of poultry would no longer be permitted (Figure 2), and ordered a complete ban on the keeping of laying hens in cages by 1999 (SFS, 2003). Acceptable alternative poultry housing systems would be required to fulfill the following criteria (Tauson, 2003):

1. neither animal health nor producer working conditions are diminished
2. beak trimming is not permitted
3. the use of medication will not increase
4. compulsory testing of all new systems for commercial production in Sweden is required to assess animal welfare.

In 1995, when Sweden became a member of the EU, a fifth condition was introduced:

5. Swedish egg production must not suffer as a result of competition from foreign cage egg production.

The compulsory testing criteria require that all applications for approval of new housing systems must be presented to the SAWA, and the evaluation is conducted by the SJV (Tauson and Holm, 2001). The assessment is first carried out in an experimental setting. If results are deemed acceptable, the manufacturer is permitted to test the housing equipment in a commercial setting. Equipment for a maximum of 100,000 hens or 10 farms may be installed for poultry systems. At 35 and 55-65 weeks of age, 100 randomly selected birds are assessed for aggressive pecking and feather pecking behaviour, use of nests, perches and litter baths, health is scored by assessing measures such as plumage and foot condition and wounds caused by pecking, and live weight is obtained. Predefined limits, expressed as a percentage of the 100 birds, are used to evaluate the system. Ammonia, carbon dioxide, dust, temperature and humidity levels are also measured. An isolated inadequate result may be exempted if the manufacturer agrees to make required changes to the system, or if the measure was not a direct result of the housing system (Tauson and Holm, 2001).

By 1997, no alternative layer housing systems capable of fulfilling the above criteria were yet available, and approximately 80% of all Swedish layer flocks were still housed in conventional battery cages. Feather pecking, cannibalism, poor air quality, parasitic infections and conditions such as bumblefoot were issues of considerable concern. The suggestion to amend the wording of the 1998 AWO to accommodate enriched cage systems was presented to parliament and in a majority vote, 80% of the members opted in favour of the change (Tauson, 2003). The amended AWO stipulated that only those cages providing a nest, perch and litter box and satisfying the natural behaviours of the birds would be permitted (SFS, 2003; Tauson, 2003).

In addition to banning beak trimming, Sweden also prohibits the use of antibiotics, synthetic colourings and offal in feed, and does not permit the use acaricides treat mites (Open Agriculture, 2004; Tauson, 2004a). For all cage systems, a maximum of three tiers is permitted, to ensure proper visual inspection of the birds. This is especially important for furnished models where nesting and litter facilities are located at the rear of the cage, which increases inspection difficulty (Tauson, 2003).

6.5.4 The Evolution of Enriched Cages for Commercial Production in Sweden

The shift from conventional battery cages to enriched cage systems was by no means a simple achievement. Prior to AWA and AWO requirements for provision of a perch and claw abrasive device for caged hens, neither cage manufacturers nor producers were eager to incorporate changes to conventional cages, even those that would seemingly improve hen welfare. Since legislative requirements were not in place to enforce change, welfare needed a link to economy (Tauson, 2004a). For example, in Sweden, the introduction of solid sides in battery cages reduced aggressive and feather pecking between neighbours and resulted in a 20-25% improvement in plumage cover. Since this translated to a significant reduction in feed consumption, solid sides became commercially accepted. Also, decreasing the slope of the cage floor was shown to reduce the incidence of toe pad hyperkeratosis, a condition resulting from pressure on the claw fold when birds stand on sloping floors, and reducing the height of the slope was also linked to a reduction in the number of cracked eggs (Tauson, 2004a).

An effective approach to encourage change is to focus on providing solutions rather than criticisms, advises Tauson (2004a). While constructive evaluation is necessary, a solution should always be provided for that which is criticized. It is more effective to show a manufacturer or producer a system that works, then to simply point out the faults of the system in question (Tauson, 2004a). This philosophy was fundamental in encouraging acceptance of enriched cage systems. With the introduction of the Swedish beak trimming policy, producers were reluctant to risk outbreaks of cannibalism in aviaries and deep litter systems, since this might render Swedish egg production less competitive than foreign egg production. An intermediate housing system was needed, and in the late 1980's, enriched cage research began at the Funbo-Lövsta Research Center in Uppsala, Sweden. The Get-Away cage was the first system considered as a potential model for groups of 15-25 birds (Tauson, 2003). Later studies focussed on units modelled after the Edinburgh Modified Cage (EMC), a system intended for 4-6 birds. For economic purposes, modifications were made to increase group size to 8 hens (Tauson, 2003). The Comfort Cage, developed by the Victorsson AB Company, was one such model to emerge (Figure 3). The system provided 3 tiers of cages equipped with a nest, perch and litter facility (Tauson and Holm, 2001). In May of 1998, after 6 years of research and design improvement in an experimental setting, the Comfort Cage (Figure 4) was accepted for field trials and was introduced onto 8 farms, housing 78,000 birds. This system was the first enriched, small group cage model to be tested in a commercial setting, and in October 2000, received final approval for commercial use (Tauson, 2003; Tauson and Holm, 2001). Although the Comfort Cage fulfills the technical requirements of the new Swedish AWO, studies with this cage system have continued and improvements to design are ongoing. Increases to the amount of perching space, and nest and litter space have also been required to accommodate the EU directive. In 2001, the Comfort Cage system could be found in 20 poultry barns across Sweden, housing approximately 250,000 birds (Tauson and Holm, 2001).

A different style of enriched cage, the Big Dutchman Aviplus (Figure 5), was introduced in 1997. This system housed 10 birds, and the nest, litter facilities and belts were situated at the rear of the cage. The Aviplus was approved for commercial use in 2001. Currently, Big Dutchman, Hellmann Poultry, Triotec and Victorsson furnished cages are commercially available in Sweden (Tauson, 2003).

Sweden was the first country to adopt furnished cages for commercial use (Tauson, 2003) and it has been suggested that these systems will gain little acceptance outside Sweden, as producers become more proficient at managing non-cage systems (Appleby, 2003). However, it is conceivable that the availability of an enriched cage environment permitted the EU ban on conventional battery cages. Without the enriched cage, a ban on cage systems might have prevented the EU egg industry from remaining competitive with world markets, and would therefore likely not have occurred (Appleby, 2003).

6.5.5 Alternative Systems

While it is clear that no housing system can adequately accommodate all of the needs of the birds, the producer, the consumer and the industry, the housing system chosen will ultimately depend on the market demand for different categories of eggs (Tauson, 2004a). Regional welfare directives, such as regulations on beak trimming or medicating animals, may also influence housing choice. Regardless of the system in place, the results must be continuously assessed and problems must be discussed. Dissemination of knowledge and sharing of information and resources is the only way to solve housing problems (Tauson, 2004a).

Selecting the right breed for the right housing system is fundamental to successful production. In Sweden, where beak trimming is not permitted, feather pecking is more prevalent in brown, medium bodied genotypes than in SCWL's (Tauson, 2003; Tauson and Holm, 2001). However, certain genotypes of both brown and white strains have been problematic regardless of the housing system, and are no longer commercially available (Tauson and Holm, 2001). Lohman LSL hens are a very docile breed that maintain good plumage condition and adapt well to deep litter, aviary and free range systems. LSL hens lay large numbers of white, medium weight eggs and generally do not require beak trimming, making them a suitable breed for Swedish production. LSL hens feather peck less than Lohman Brown (LB) birds, are more explorative than the Brown genotype and use nest boxes well, a trait that also endears them to non-cage production systems (Tauson, 2004).

The environment in which pullets are reared is also an important consideration. Since the 1960's it has been customary in Sweden to raise birds on floor litter. However with a shift to enriched cages and aviary housing systems, it is become apparent that both the birds and the producer benefit if hens have prior exposure to nest boxes, perches and tiered systems, in addition to litter access (Tauson, 2004a).

6.5.5.1 Swedish Experience with Furnished Cages

Tauson (2004a) regards furnished cages as a highly suitable alternative housing system for laying hens, particularly where beak trimming is not permitted, since they provide birds with opportunities to nest, perch and dust bathe, and limit aggressive interactions between conspecifics. While he is adamant that nest sites are of critical importance, Tauson suggests that litter facilities serve more to occupy birds and permit play, than to satisfy an innate need. However, he maintains that occupying hens is essential for controlling feather pecking and cannibalism, particularly for non beak-trimmed birds (Tauson, 2004a). Tauson (2004a) has observed that in flocks where the incidence of cannibalism and aggression has been high in furnished cage systems, it has been considerably worse for birds of the same strain housed in conventional systems.

The inability to beak trim also encourages a conservative approach to group size. While colony cages of 30-40 birds would be more economically feasible and would provide more overall space per bird for movement and exercise than cages with 5 or 10 hens, the risk of cannibalism would also increase with increasing group size (Hughes and Wood-Gush, 1977; Tauson, 2004a). Wall et al. (2004) examined the use of pop hole systems in furnished cages of 16 hens, to determine whether partitioning of large group cages would improve the ability of hens to escape from, or avoid cannibalism, feather pecking and aggressive interactions. Although the pop holes were well used and did not interfere with bird distribution throughout the cage, the overall lack of aggression in both open and partitioned cages made it difficult to determine the effectiveness of the pop hole design for groups of that size (Wall et al., 2004). Large group sizes can also lead to inspection difficulties and often 2 individuals are required to simultaneously inspect the cage (Tauson, 2004a).

Studies conducted at the Funbo-Lövsta Research Center and commercial farms have determined that productivity, mortality and feed conversion efficiency measures are comparable for birds housed in furnished cages and conventional cages (Tauson and Holm, 2001; Tauson, 2003). Commercial mortality values have ranged between 4.2-8% for furnished systems and 4.9-5.9% for conventional cages (Tauson, 2003). Although a slight increase in the incidence of mortalities has occasionally been observed towards the end of the production period in furnished cages, this might be attributed to the larger group size. Feed conversion ratios appear to be improved in furnished cages. Superior plumage condition of birds in furnished cages and birds perching in close proximity likely serve to retain heat energy, which more than compensates for the energy requirements of increased movement, stepping onto perches and dust bathing. Increased movement and exercise also contributes to improved bone strength of birds housed in enriched cages as compared to conventionally housed hens (Tauson, 2003).

A dramatic reduction in the proportion of cracked and dirty eggs in furnished cages has been observed as nest designs have evolved. Inclusion of plastic curtain strips at the end of a nest box or egg saver wires that are raised every 10-20 minutes during peak lay, for example, serve to reduce the speed at which eggs exit the nest box and prevent egg cradle collisions (Tauson, 2003). This is of particular importance when nests are narrow and deep in design and egg roll out is concentrated, or when eggs are laid high up in the nest box and accumulate speed as they roll towards the cradle (Wall and Tauson, 2002). Tauson (2004a) has observed a 20-40% reduction in the proportion of cracked eggs when curtains are present. It has also been suggested that more frequent operation of the egg belt during peak production times might serve to reduce the incidence of egg collisions (Wall and Tauson, 2002). A higher incidence of dirty eggs has been observed in systems such as the Aviplus model (Big Dutchman), where nest boxes and egg belts are located at the rear of the cage. The presence of additional facilities at the rear of the cage may reduce light intensity, deterring bird movement in this area, and thereby impairing the removal of manure through the cage floor (Tauson, 2003). Perch design and location may also encourage manure build-up and reduce egg hygiene. Continued research and experience with furnished systems will lead to improvements in nest and perch design and location, advancements in the construction of egg saver devices, and increased understanding of hen behaviour, and will serve to further improve egg quality traits (Tauson, 2003).

Extensive use of the facilities provided in furnished cages would suggest that these amenities are important for meeting the behavioural needs of the birds. In furnished cages, nest use consistently ranges between 90-100% of hens, suggesting that nesting is the most deprived behaviour for conventionally housed birds (Tauson, 2003). Eggs are seldom laid in the litter box and trials with Victorrson cages have shown that fewer than 8% of birds remain in the nest box overnight (Tauson and Holm, 2001).

Perching is also a high priority behaviour for hens. Commercial testing in Sweden has demonstrated that between 70-95% of birds perch at night (Tauson, 2003) and use of the perch increases when dawn to dusk light simulation is used (Tauson and Holm, 2001). Prior to 1995, furnished cages in Sweden were required to provide a minimum of 12 cm of perch space per bird (Tauson, 2003). EU requirements however stipulate a minimum of 15 cm perch space per hen (Europa, 2005b). Addition of perch space has proven difficult within furnished cage systems since it requires cross over of perches. This arrangement not only deters birds from perching at cross sections, but also encourages build-up of fecal matter, which increases susceptibility to infection. For example, an outbreak of Coccidiosis in an Aviplus Big Dutchman system was attributed to accumulation of manure under the perch systems (Tauson, 2003). Regular removal of manure is also essential to prevent build up under the perch arrangement, and Tauson (2003) recommends two belt runs each week. This will also ensure that birds can not peck at manure through the cage floor and that claws are not in contact with fecal matter, which may decrease egg quality. Continued research will provide solutions for perch positioning and design. Experiments with perches in the Victorsson model have already prompted changes that have led to improved hen foot and claw condition and facilitated entry into the litter box (Tauson and Holm, 2001).

Location, ease of access and size of the litter box are among several known factors to influence use of this facility (Tauson, 2003). In the Aviplus system for example, the litter box is positioned lower in the cage and is therefore easier to enter than a litter box positioned on top of the nest box. Strain type also appears to influence use of the facility. Brown, medium hybrids are observed to use the litter box more frequently than SCWL's. However, individual preferences may be a stronger impetus for litter use than breed type. Wall and Tauson (2004) implanted hens with transponders tags to monitor hen use of the litter facility. The authors found that while 5-10% of the hens used the litter on a regular basis, one third of the birds did not use it all. This might suggest that only dominant hens access the litter box (Tauson, 2004a). Alternatively, given that sham dust bathing is also seen in enriched cages (Tauson, 2004a), it is possible that the litter facilities provided in furnished cages are inadequate for the hens. Birds reared on litter are also more inclined to use the litter box than birds reared in cages (Tauson, 2004a).

An effective method of deterring hens from laying eggs in the litter box is to provide a closing mechanism that limits litter access during peak laying times (Figure 6). In Sweden, litter facilities must be opened 8 hours after lights have been turned on. Litter boxes are generally filled by hand in small production facilities, however efficient delivery mechanisms have also been developed to facilitate management on larger operations. For example, a robotic device developed in Sweden automatically navigates the aisles of the barn and delivers substrate via tube arms. Auger systems positioned at the partition between cage systems and litter belts are more recent developments (Tauson, 2003). Preferred substrates include sawdust, sand and wood shavings. Sawdust, a fine material, is inexpensive and abundant in Sweden and is the most commonly used substrate. Wood shavings, which are course in structure and do not penetrate the plumage completely are less preferred by hens (Tauson, 2003). Peat is inexpensive and is favoured by hens but is very dusty and may have consequences for occupational safety (Tauson, 2004a). Malfunctioning door mechanisms and litter delivery systems have been reoccurring problems in enriched cage systems and improvements to these designs are ongoing (Tauson, 2003).

6.5.5.2 Swedish Experience with Non-cage Systems

In 2001, Sweden began to experience a shortage in domestic egg production. This was attributed to the changeover to alternative systems, which had caused a delay in production while equipment was modified and had deterred some producers from continuing laying hen farming. To increase domestic egg production, the Swedish government offered financial incentives, encouraging producers to shift to floor systems. Producers from swine and cattle industries also switched to egg production, to take advantage of the premiums offered (Tauson, 2004a).

Aviary systems are more intensive than enriched cage systems and enable higher barn stocking densities. However, Tauson (2004a) argues that grouping large numbers of birds together in aviaries increases the risk of feather pecking and cannibalism. Whereas in a cage system, a bird inclined to peck might only have access to a small group of hens, in aviaries such birds could affect a much larger number of conspecifics. Although hens housed in aviary systems are not confined to a cage area and are better able to escape from aggressors, cannibalism in aviaries can nonetheless lead to variation and unpredictability in mortality measures. Strain choice is therefore of utmost importance for aviary systems (Tauson, 2004a).

Tauson (2004a) agrees that in addition to providing opportunities for nesting, perching and use of floor litter, aviaries encourage movement, exercise and flight, which improve hen health. However, he cautions that parasites can be problematic, particularly if legislation restricts the use of medications. For example, recent cases of *Escherichia coli* and *Erysipelas* have emerged in non-cage systems in Sweden (Tauson, 2004a).

The Marielund aviary, developed on the Marielund Farm, approximately 7 km east of the Funbo-Lövsta Research Center has been one of the more successful aviary systems in Sweden. It is similar to the Swiss Natura System, and has a resting area at the highest level, where only perches and drinkers are located. To reach the resting area, birds must travel past the nest boxes. This design helps to discourage floor laying (Tauson, 2004a).

High quality egg production is achievable in aviary and deep litter systems provided the incidence of floor laying is maintained at low levels (Tauson, 2004b). As producers gain experience with non-cage systems and improvements to housing design are implemented, egg quality measures also appear to be improving. In 2001, Tauson and Holm determined that egg quality was higher for birds housed in enriched cages than for matched birds housed in deep litter systems. In this study, 2% of caged eggs were laid outside the nest box whereas in deep litter systems 3.5% of eggs were laid on the floor. Today, the percentage of floor eggs in deep litter and aviary systems typically ranges between 0.5 - 1.0% (Tauson, 2004a). While floor laying levels below 2% are considered acceptable, levels may vary irregularly.

Tauson and Holm (2001) also found that birds housed in enriched cages had superior plumage condition and fewer wounds to the comb and caudal areas of the body than hens housed on deep litter, suggesting increased feather and aggressive pecking in floor systems. Inferior plumage condition and increased energy requirements for movement may have contributed to the higher feed consumption requirements of floor housed birds. A higher incidence of bumblefoot was observed for birds housed in the floor system and likely resulted from contact with litter and lower hygienic conditions. Mortality differences however, were not apparent between systems (Tauson and Holm, 2001). Tauson (2004b) agrees that management strategies can be adopted to improve the productivity and welfare of hens housed in alternative systems, but suggests that ultimately, permitting beak trimming and the use of pharmaceuticals may be necessary to achieve acceptable results.

6.5.6 Summary and Conclusions

As awareness and understanding of animal welfare have increased, Sweden has adapted its agricultural industry to incorporate developments that promote humane rearing of animals, prosperity for producers, sustainable production and social acceptance. The Swedish government has responded to public concern and pressure by establishing precise animal welfare policies that protect the physiological and behavioural needs of agricultural species, provide specific guidelines for producers, and emphasize food safety. By exceeding EU directive requirements, these policies have helped to protect Swedish production from foreign market competition.

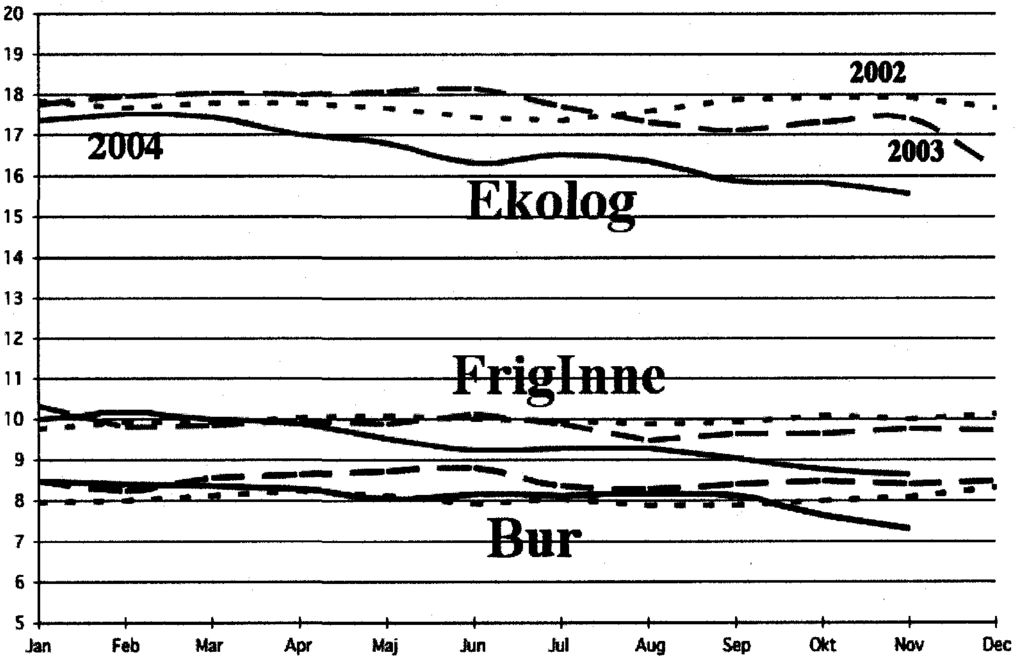
For the laying hen industry, the Swedish government and egg boards have facilitated the conversion to alternative housing systems by providing financial incentives and setting premium egg prices. While legislative policies are strictly monitored, producers recognize that maintaining health and well being of their animals is necessary to ensure success, and actively engage in voluntary measures and develop initiatives that will improve product quality. Sweden's strict legislative policies have also served to secure consumer trust and set precedence for future industry growth.

The development of enriched cage housing systems for laying hens was a significant achievement and continued developments in cage design and layout have resulted in increased use of facilities by the hens, improved management conditions and increased egg quality. The Swedish initiative to support humane rearing of animals and sustainable production is continuing with Sweden's movement towards organic production. Strategic programs are being developed to provide both financial support and a knowledge base to assist and sustain growth in organic production. Analyzing problems and trends, developing guidelines and policies, implementing a unified certification system, providing educational programs for producers and consumers, and engaging major food chains are part of the plan to gain consumer trust and awareness, establish product availability and affordability, and provide producers with access to advice and knowledge.

From the Swedish experience, it is apparent that developing well-designed and functional enriched cage systems takes time and experience. Continued improvements to alternative designs and matching bird strains with the appropriate housing system will determine whether policies regarding enriched cage systems, beak trimming, and the use of pharmaceuticals will change in Sweden, or whether these policies will ultimately become international standards.

6.5.7 Figures

Figure 6.18 Producer prices for Swedish eggs, Swedish Krona (SEK) per kg



Bur = Cage
FrigInne = Perchery/barn/deep litter
Ekolog = Organic

1 Canadian Dollar (CAD) ≈ 5 Swedish Krona (SEK)

Adapted from Eggs Sweden, 2004

Figure 6.19 An untrimmed Swedish laying hen. Beak trimming has not been permitted in Sweden since1988.

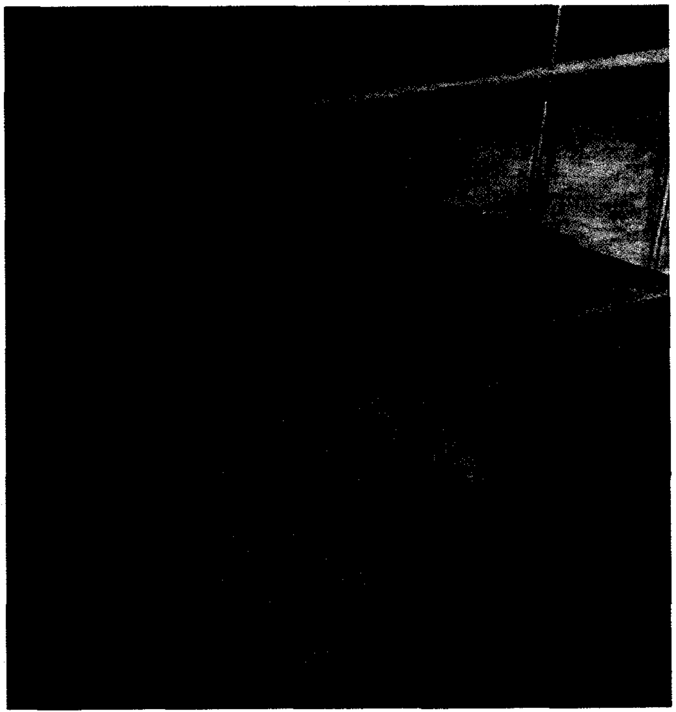


Photo courtesy J. S. Church

Figure 6.20 The Comfort Cage by Victorsson houses 8 hens and provides a nest box, litter facility, perches and claw abrasives.

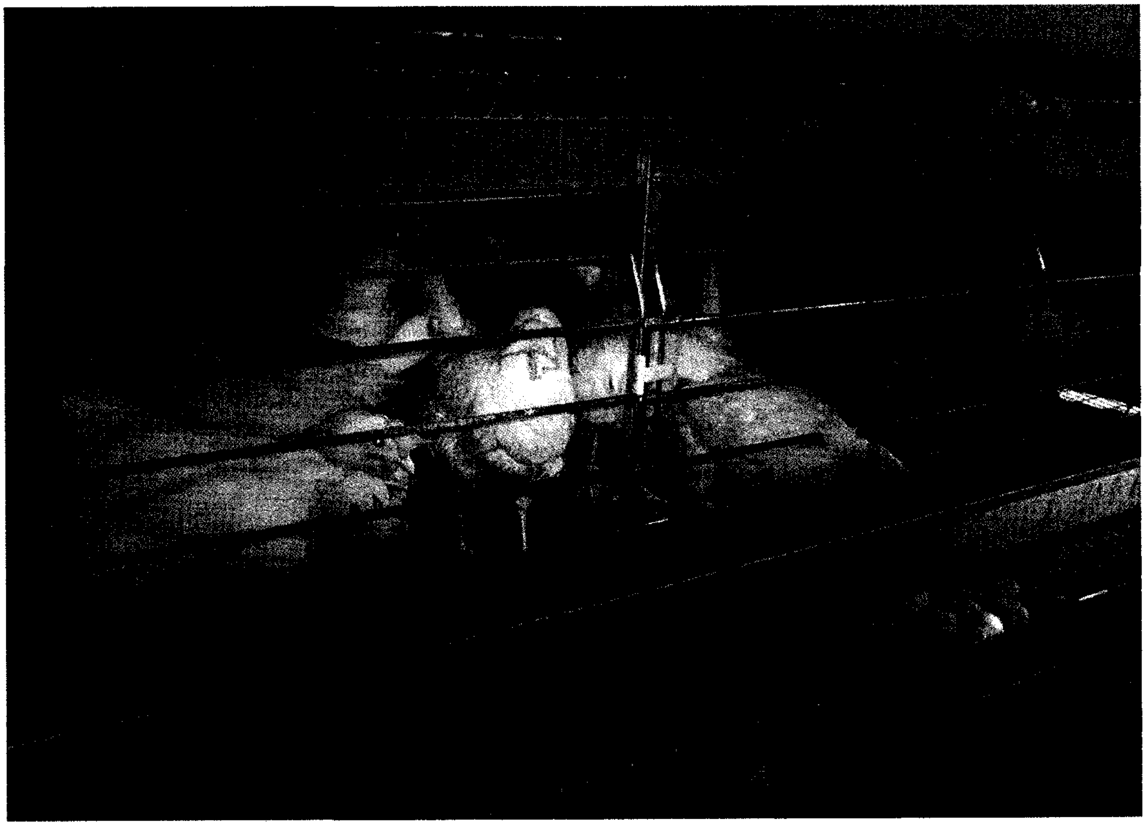


Photo courtesy J. S. Church

Figure 6.21 Comfort Cage systems at the Funbo-Lövsta Research Station in Uppsala, Sweden.

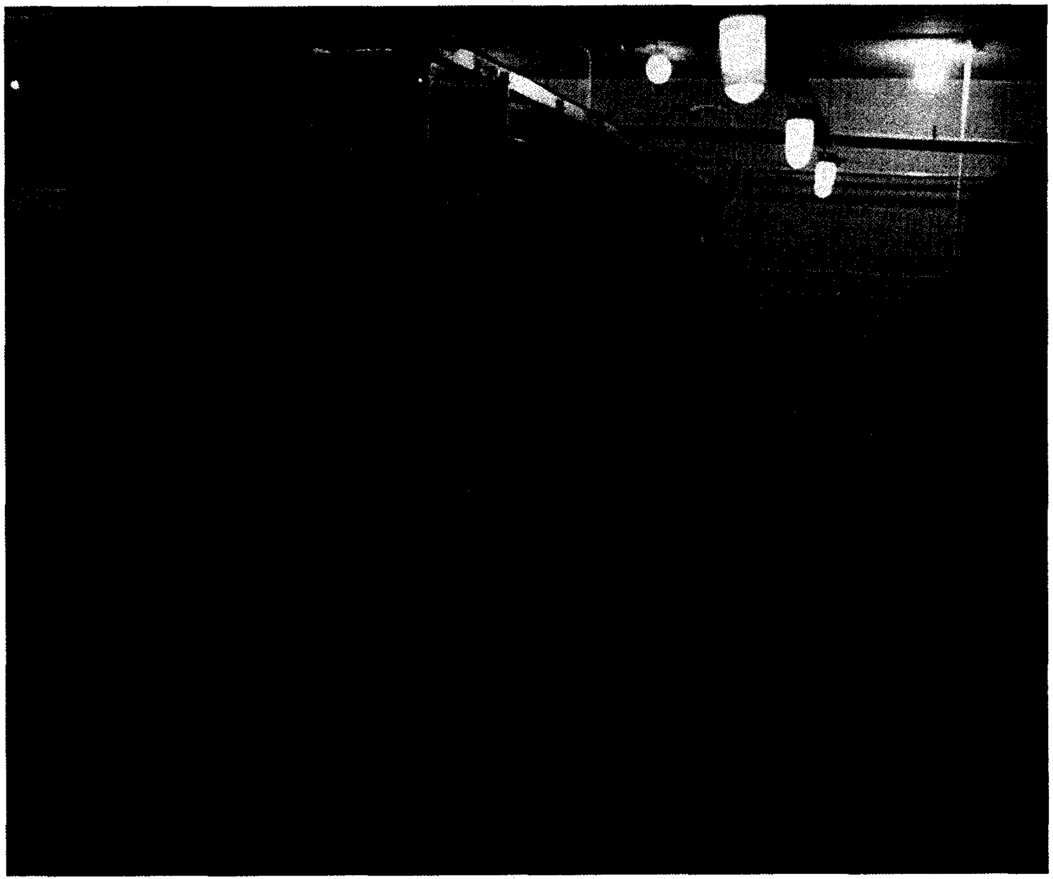


Photo courtesy J. S. Church

Figure 6.22 The Big Dutchman Aviplus enriched cage houses 10 birds, and the nest and litter facilities are located at the rear of the cage.

Photo courtesy J. S. Church

Figure 6.23 Closing mechanism for the litter box in a Victorrson model enriched cage.

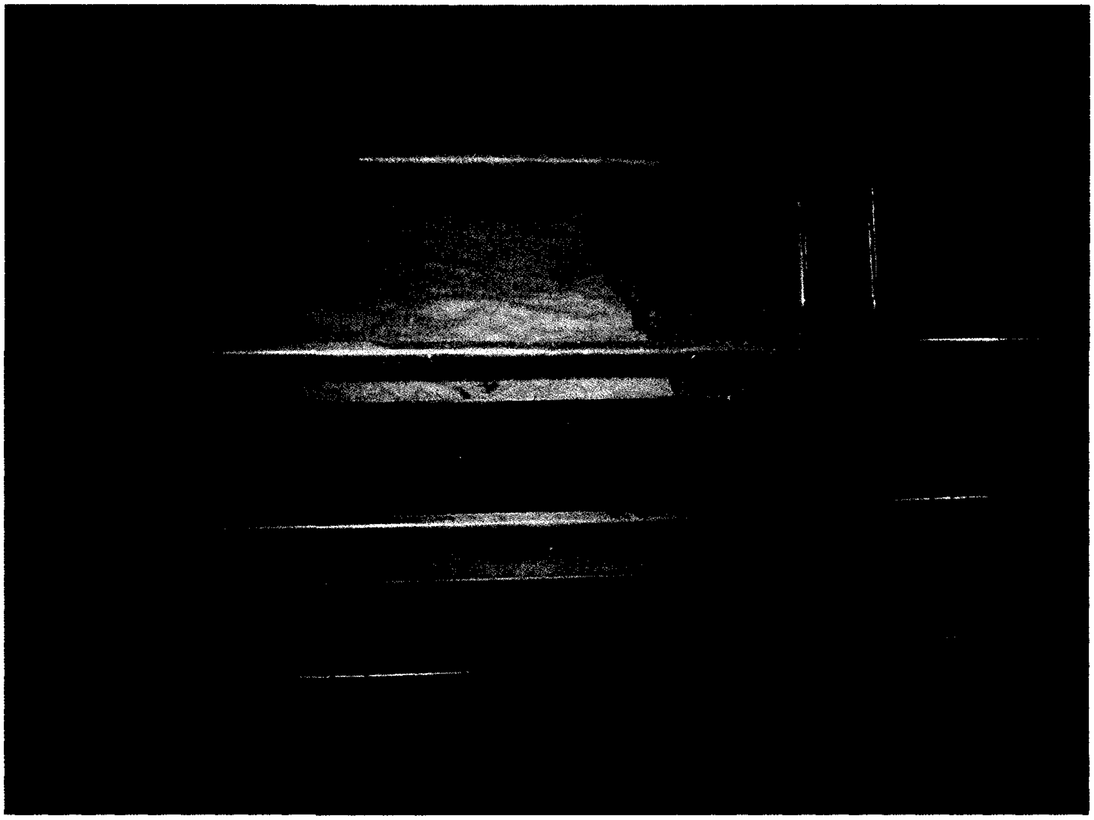


Photo courtesy J. S. Church

6.6.1 Figures

Figure 6.24 Kleinvoliere (small aviary) system.

Photo courtesy Lars Schrader

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Chapter 7

General Summary and Conclusions

It has been well established that the despite the production benefits of housing laying hens in conventional battery cages, the welfare of birds kept in these systems is compromised by behavioural restrictions and confinement. As a consequence, laying hen production systems have begun to evolve worldwide to better meet hen behavioural and physiological needs, while simultaneously accommodating the demands of intensive production. The goals of this research were to provide North American producers with viable cage housing options for promoting laying hen welfare while maintaining the benefits of cage systems, as well as to expose producers to alternative cage and non-cage housing systems that have successfully been implemented in Europe. Specific objectives included designing a modification to the conventional battery cage that was based upon the findings of previous modified cage research and that could be incorporated into existing cage capital, and assessing the welfare and productivity of Shaver White Leghorn hens housed in conventional cages, the modified systems, and a commercially available furnished colony system.

In Chapter 2, an observational investigation of the behaviour of MOD and CONV hens was conducted to evaluate whether the nesting facility incorporated in MOD cages improved hen welfare during the prelaying and laying period. It was clearly evident from the observations conducted on hens who had oviposited that birds in CONV were more frustrated than hens in MOD. CONV hens exhibited more stereotyped bobbing, escape and pacing activity, and performed these behaviours for longer durations than MOD hens. Hens in CONV cages were also more restless, and walked about the cage more often, stood more frequently and rested for shorter periods, and were more aggressive than birds in MOD, displaying increased frequencies of aggressive pecking and displacement behaviour. Moreover, the elevated levels of frustrated behaviours observed in CONV, and the rapid rate with which these behaviours increased in frequency prior to oviposition provided additional evidence that frustration in CONV resulted from the inability of these birds to express normal nesting behaviour. Even comfort behaviours expressed in CONV appeared frantic and stereotyped, and unlike hens in MOD, who actually dozed and slept while nesting, CONV hens were not observed to rest during the prelay period. In the absence of a nest site, CONV hens also recovered less readily from the daily stress of oviposition. The provision of a nest site in MOD therefore clearly reduced hen frustration and improved hen welfare, and hens in MOD showed an obvious preference for laying in the nesting environment provided.

Chapter 3 examined behavioural indices of welfare for hens who were housed in commercially-available furnished colony cages. In this study, the intent was to examine the contribution of a dustbathing facility to hen welfare by observing dustbathing behaviour when hens had access to an actual dustbathing facility and loose and non-litter substrates, or when hens had access to the substrates but not a bathing facility. Dustbathing is an important maintenance behaviour, but because the absolute motivation for the behaviour has not been clearly defined, and because there are logistical and economic concerns with incorporating dustbathing facilities in cage systems, providing hens with specific dustbathing facilities to express this behaviour has not been a priority in cage housing systems. A comparison of the frequencies with which true and sham dustbathing occurred in CWDB and CWODB cages, and the number of hens who bathed revealed that although sham bathing was not prevented by the presence of a dustbath in CWDB, combined true and sham bathing activity was increased. In addition, latency to bathe in loose peat substrate was shorter and duration of true bathing was longer in CWDB, suggesting that in the presence of a loose-litter dustbathing facility, hens were better able to express dustbathing behaviour. High frequencies of bathing activity, shorter than normal dustbathing bouts, similar frequencies and durations of sham bathing bouts in CWDB and CWODB, and observations that true bathing in CWDB was frequently interrupted or hens were displaced from the dustbath, indicates however that in large group systems, social competition for the dustbath was problematic and that dustbath design must better accommodate synchronous bathing behaviour. Despite previous suggestions that sham bathing on the cage wire floor, or on non-litter substrates may be sufficiently adequate to meet hen behavioural needs, the findings from this work suggest that domestic hens are highly motivated to perform dustbathing in loose litter, have not adapted feather maintenance behaviour to a dustless environment, and that provision of adequate dustbathing opportunity in cage systems is therefore necessary to improve hen welfare. Future studies should continue to examine individual and group motivation for bathing in domestic fowl and improvements to dustbath designs to better accommodate synchronous bathing behaviour in socially complex, large group cage settings.

A principal and well supported argument in opposition to conventional battery cage housing is that natural movement and load bearing activity are prevented in these systems leading to disuse osteoporosis, metabolic disorders, bone fractures and consequently, considerable hen suffering. The purpose of Chapter 4 was therefore to compare bone health of hens housed in CONV cages, MOD cages where hens had access to a perch and somewhat greater freedom of movement, and CWDB and CWODB cages in which hens could perch, jump up to the dustbath, move more freely about the cage, and perform wing movements such as stretching, flapping, bathing and even flight. Increased total bone mineral density, bone mass, cortical bone area and mass and bone breaking strength values in the femur and tibia of MOD, CWDB and CWODB hens, and greater area of trabecular bone space in CONV, indicated that structural bone preservation, and consequent improved leg bone strength was afforded by movement and load-bearing activity in the three furnished systems. However, only in CWDB and CWODB were cortical bone density and mass, and breaking strength improved in the humerus, suggesting that inclusion of a raised amenity in cage systems was necessary to promote wing-loading. Notably, since no correlation was apparent between egg production or quality and bone quality measures, improvements in bone condition were not the result of reduced egg production or quality, suggesting that structural bone maintenance and egg production demands could be simultaneously met when hens had opportunity for movement and load bearing activity. It should be noted that space limitations for perching in MOD likely only permitted two of three hens to perch simultaneously, and social dynamics within the cage may have further dictated perch use. Similarly, as suggested in Chapter 2, social competition for the dustbath, an amenity that provided increased opportunity for wing loading, might suggest that bone loading opportunities were not fully realized by all hens in colony cages. Therefore, improvements to bone density and breaking strength might have been further exploited by adapting furnished cage designs to maximize hen access to amenities such as the perch and raised dustbath. The findings from this study indicate that bone health and therefore hen welfare, was clearly improved by providing caged hens with increased opportunity for movement and bone-loading activity, and that improvements to wing bone health were possible when hens had increased opportunity for wing loading. Future studies must continue to examine the physiological and economic implications of improving bone strength through movement and load bearing activity, and how increasing bone density and strength impacts the incidence of bone breaks and metabolic disorders over the course of the laying cycle, and during depopulation.

The goal of Chapter 5 was to study the impact of each of the housing conditions on condition and production indices of hen welfare. Reduced feather condition and wound scores, and a higher incidence of cannibalism in colony cages suggests that social instability and dominance structures in large group cages contributed to detrimental feather and aggressive pecking. Despite additional room for hen movement in colony cages, and the presence of cage amenities that permitted expression of natural and load bearing movement and that contributed to hen welfare (Chapters 3 and 4), large group size in the colony cages was not without significant disadvantages to the well being of hens in these systems. Reduced feather cover in CWDB and CWODB also likely contributed to increased feed consumption and reduced feed conversion efficiency observed by hens in these systems. Notably however, feather condition was improved in CWDB over CWODB, suggesting that in addition to the observed behavioural and structural bone advantages afforded by the dustbathing facility (Chapters 3 and 4), in large group cages the dustbath also contributed to improved feather cover. Permitting hens to express dustbathing behaviour may have contributed both to feather structural maintenance, and to reduced frustration and resultant feather pecking activity. These findings further emphasize the importance of providing dustbathing amenities for caged hens. It is also possible that improved facility design would further reduce hen frustration, and thereby further contribute to improved feather cover in the colony environment.

In small group MOD cages, feather cover and foot condition were improved compared with measures for hens in CONV, CWDB and CWODB, providing additional evidence that reducing hen frustration through provision of a nest site, and permitting hens to perch promoted hen welfare. Furthermore, maintaining small group size was beneficial to the welfare of the Shaver White Leghorns examined in this study. Further studies examining strain differences in adaptability to the colony environments are necessary to find the most suitable strain for large group cage systems.

Egg production did not differ between any of the housing conditions, and increased cracking was only observed in MOD, CWDB and CWODB when eggs were allowed to accumulate in the egg tray. Notably, however, measures of eggshell thickness and weight indicated that eggshell quality was improved in colony cages. This would suggest that in addition to preserving structural bone (Chapter 3), hens in colony units also produced better quality eggs than hens in MOD or CONV. These findings suggest that housing hens in furnished colony cage environments where bone loading is possible may improve the efficiency of calcium metabolism. Future studies should therefore examine parameters of calcium utilization for hens housed in environments where movement and bone loading are encouraged.

From the combined evaluation of hen behavioural, physiological, condition and production indices examined in Chapters 2, 3, 4 and 5 it can be concluded that the welfare of White Leghorn hens was improved in MOD, CWDB and CWODB cages over conventionally-caged hens, but that welfare concerns must still be addressed in these systems. MOD cages provided a small group housing environment in which hens could express prelaying, nesting and perching behaviour and benefited from improved leg bone strength, and reduced frustration and aggression. Producers could easily modify existing cage capital to achieve these welfare and production benefits. Space limitations in MOD cages and the absence of a raised amenity however, prevented hens from performing wing loading movement, and may have limited perch use. In the colony cages, hens further benefited from the larger cage space, opportunity to perform behaviours that encouraged wing loading, and in CWDB, the opportunity to express true dustbathing behaviour. Large group size and competition for cage resources however may have contributed to hen frustration leading to increased aggression, feather pecking and cannibalism, thereby reducing hen welfare. For cage systems, continued research is necessary to achieve a balance between optimizing hen access to cage amenities and space for movement, minimizing social aggression and competition, and minimizing capital costs per hen housed. Ongoing research in alternative housing environments in Europe has contributed to the successful implementation of cage and non-cage systems, examples of which were examined in Chapter 6.

North American producers considering the transition to alternative cage and non-cage laying hen housing systems could greatly benefit from the experience of those who, either through market demand, legislative policies, or by choice have evolved beyond housing laying hens in conventional battery cages. Chapter 6 examined alternative layer housing environments in the Netherlands, Switzerland, Sweden and Germany and outlined beneficial management strategies that producers and researchers have adopted to optimize welfare and productivity in these systems. In the Netherlands and Switzerland, aviaries are the most predominant layer housing systems and are frequently combined with access to a range or covered veranda. Sweden was the first country to adopt small group enriched cages for commercial production, and this system has proven more successful than non-cage environments since beak trimming is prohibited in Sweden. In Germany where, until 2007, legislative policies threatened to prohibit the keeping of laying hens in all cages systems, developments to a small aviary system have been ongoing. Irrespective of housing system, producers and researchers in each of these countries agree that conditions of the rearing period must resemble that of the production period and that finding the right bird for the right system is crucial. In non-cage systems, strategies for reducing the incidence of floor eggs, improving air quality, and maximizing productivity can be adopted. Although the transition to alternative housing systems may be challenging, the satisfaction of achieving a balance between hen welfare and successful production can be extremely rewarding.

Alternative cage and non-cage housing systems provide welfare benefits to hens that cannot be realized in conventional battery cages. Laying hen housing environments must continue to evolve with our increased understanding of hen behavioural and physiological needs and preferences. Ongoing research will help to identify strain suitability for different housing environments and will result in improvements to system design and layout, which will enhance use of facilities, continue to improve hen welfare and impact production efficiency.

Appendix A

Correlation Coefficients (r) for Bone Quality Measures and Indices of Egg Production or Quality

Table A.1 Correlation coefficients (r) for bone quality measures and indices of egg production or quality for treatments combined *(*P <0.05).*

Bone quality Measure	Hen-day Production	Stored Egg Weight	Specific Gravity	Eggshell Thickness	Eggshell Weight
Femur					
Total Density	0.0049	-0.11072	0.21284	0.18622	0.08249
Total Area	-0.13434	0.3375*	-0.16994	-0.14288	0.20386
Total mgQCT	-0.06638	0.05835	0.1028	0.09175	0.16255
Trabecular Density	0.13127	-0.05095	-0.20113	-0.09912	-0.08767
Trabecular Area	0.03901	0.14273	-0.20252	-0.15276	-0.02793
Trabecular mgQCT	0.08516	0.09019	-0.22844	-0.17396	-0.06048
Cortical Density	0.13841	-0.01176	-0.16543	-0.07812	-0.08293
Cortical Area	-0.11288	0.0532	0.15643	0.10847	0.14381
Cortical mgQCT	-0.08839	0.04727	0.15904	0.12719	0.1552
Breaking Strength	0.00407	-0.11175	0.09772	0.0266	0.00309
Humerus					
Total Density	0.07368	-0.25377*	0.2377	0.18325	-0.02749
Total Area	-0.03561	0.16473	-0.19819	0.25455*	-0.08573
Total mgQCT	0.06179	-0.20469	0.18612	0.10487	-0.05029
Trabecular Density	-0.02417	-0.20481	0.11229	0.05467	-0.1161
Trabecular Area	-0.0465	0.16394	-0.21745	-0.27406*	-0.10978
Trabecular mgQCT	-0.04792	-0.232	0.12233	0.05002	-0.19601
Cortical Density	0.37197*	-0.22929	0.28224*	0.24341*	0.03127
Cortical Area	0.02422	-0.11185	0.21216	0.17301	0.11864
Cortical mgQCT	0.12537	-0.15427	0.25928*	0.21254	0.1123
Breaking Strength	0.19142	-0.12388	0.22604	0.26993*	0.18147
Tibia					
Total Density	0.08072	-0.14334	0.19577	0.15467	0.05764
Total Area	-0.02178	0.29813*	0.04104	0.01443	0.23711
Total mgQCT	0.06013	-0.00224	0.20808	0.14736	0.17077
Trabecular Density	0.11395	0.01047	0.00875	0.02632	0.02494
Trabecular Area	0.01098	0.16738	-0.13513	-0.04405	0.02224
Trabecular mgQCT	0.07594	0.10069	-0.14233	-0.05855	-0.01483
Cortical Density	0.10999	0.0115	-0.12409	0.01664	-0.02603
Cortical Area	-0.02742	-0.01749	0.21374	0.12021	0.12382
Cortical mgQCT	0.01774	-0.0189	0.22123	0.15793	0.14888
Breaking Strength	0.12742	-0.03423	0.1305	0.11973	0.10293

Table A.2 Correlation coefficients (r) for bone quality measures and indices of egg production or quality for CWDB treatment birds *(*P <0.05, **P<0.01)*.

Bone quality Measure	Hen-day Production	Stored Egg Weight	Specific Gravity	Eggshell Thickness	Eggshell Weight
Femur					
Total Density	0.11432	0.39994	0.46776	0.42063	0.64599*
Total Area	-0.6047*	-0.1132	-0.10957	-0.18549	-0.20765
Total mgQCT	-0.41425	0.31267	0.37235	0.30032	0.49385
Trabecular Density	-0.60014*	-0.16983	0.17699	0.21457	-0.1479
Trabecular Area	-0.24702	-0.07981	-0.56396	-0.15673	-0.40027
Trabecular mgQCT	-0.29366	-0.07188	-0.52418	-0.10473	-0.39162
Cortical Density	-0.14122	0.28538	-0.40266	0.45002	0.18531
Cortical Area	-0.14111	0.25454	0.4383	0.11133	0.43287
Cortical mgQCT	-0.18767	0.36076	0.41894	0.26741	0.5567
Breaking Strength	-0.38697	0.4257	0.45771	0.47687	0.69808*
Humerus					
Total Density	0.33006	-0.21542	0.29378	-0.17659	-0.27514
Total Area	-0.24311	-0.16165	-0.25799	-0.17237	-0.08175
Total mgQCT	0.28843	-0.30312	0.22991	-0.27412	-0.37229
Trabecular Density	----------	---------	--------	--------	--------
Trabecular Area	-0.33053	-0.04864	-0.30667	-0.05539	0.04801
Trabecular mgQCT	----------	---------	--------	--------	--------
Cortical Density	0.45171	-0.17051	0.26573	-0.08436	-0.26285
Cortical Area	0.07772	-0.1991	0.14759	-0.21453	-0.12608
Cortical mgQCT	0.1783	-0.21453	0.19549	-0.21614	-0.18094
Breaking Strength	0.29479	0.22021	0.20042	0.02868	0.33983
Tibia					
Total Density	0.13447	0.22451	0.69716*	0.45393	0.53656
Total Area	-0.39955	-0.00468	-0.26447	-0.35427	-0.15349
Total mgQCT	-0.23499	0.24756	0.47142	0.18837	0.44056
Trabecular Density	0.07065	0.18089	0.31051	0.14837	0.394
Trabecular Area	-0.06744	0.01372	-0.75002*	-0.13031	-0.2932
Trabecular mgQCT	-0.05155	0.14619	-0.70241*	-0.05831	-0.11533
Cortical Density	0.12334	0.20942	-0.37077	0.43349	0.10712
Cortical Area	-0.27283	0.1047	0.50701	0.02388	0.30251
Cortical mgQCT	-0.22136	0.2068	0.52931	0.23196	0.42387
Breaking Strength	0.12667	0.57759*	0.35617	0.73408*	0.81391**

Table A.3 Correlation coefficients (r) for bone quality measures and indices of egg production or quality for CWODB treatment birds (*P <0.05).

Bone quality Measure	Hen-day Production	Stored Egg Weight	Specific Gravity	Eggshell Thickness	Eggshell Weight
Femur					
Total Density	0.49158	-0.46818	0.11228	-0.12762	-0.40525
Total Area	-0.00608	0.08081	-0.25806	-0.55492	-0.20584
Total mgQCT	0.42011	-0.3494	-0.05877	-0.3677	-0.44162
Trabecular Density	-0.60619*	0.73437*	-0.43973	0.03429	0.59559*
Trabecular Area	-0.4706	0.28007	0.24437	0.11229	0.34721
Trabecular mgQCT	-0.66581*	0.49425	0.14547	0.16322	0.55505
Cortical Density	0.00102	-0.21187	0.31863	0.1845	0.0016
Cortical Area	0.4857	-0.38766	-0.15984	-0.4718	-0.55614
Cortical mgQCT	0.51313	-0.45547	-0.0185	-0.37599	-0.53759
Breaking Strength	0.31012	-0.63809*	-0.2101	-0.485	-0.66243*
Humerus					
Total Density	-0.00517	-0.12931	0.30462	0.15767	0.04937
Total Area	0.33427	-0.058835	-0.00124	-0.47631	-0.67742*
Total mgQCT	0.08413	-0.26978	0.27431	-0.00137	-0.1389
Trabecular Density	----------	---------	--------	--------	--------
Trabecular Area	0.25732	-0.43308	-0.07599	-0.42051	-0.54989
Trabecular mgQCT	----------	---------	--------	--------	--------
Cortical Density	-0.06643	0.02888	0.55536	0.55212	0.39124
Cortical Area	0.15332	-0.33184	0.15667	-0.23202	-0.30411
Cortical mgQCT	0.12738	-0.29573	0.27491	-0.07322	-0.182
Breaking Strength	-0.03985	-0.15182	0.44178	0.10615	-0.07556
Tibia					
Total Density	0.43155	-0.27844	0.01781	-0.20178	-0.29164
Total Area	0.14946	-0.10743	-0.13244	-0.65727*	-0.39067
Total mgQCT	0.44495	-0.27018	-0.07783	-0.47461	-0.42334
Trabecular Density	-0.48292	0.81184*	-0.31891	0.25872	0.70427*
Trabecular Area	-0.3774	0.08832	0.14704	0.2187	0.22263
Trabecular mgQCT	-0.49495	0.32989	0.05248	0.34544	0.45345
Cortical Density	0.02396	-0.09417	0.39736	0.54673	0.23304
Cortical Area	0.41649	-0.31039	-0.16294	-0.57156	-0.50449
Cortical mgQCT	0.45894	-0.34962	-0.06836	-0.47811	-0.47689
Breaking Strength	0.28287	-0.47638	0.05636	-0.48225	-0.54487

Table A.4 Correlation coefficients (r) for bone quality measures and indices of egg production or quality for CONV treatment birds *(*$P < 0.05$)*.

Bone quality Measure	Hen-day Production	Stored Egg Weight	Specific Gravity	Eggshell Thickness	Eggshell Weight
Femur					
Total Density	-0.07709	0.23155	-0.10491	0.31859	0.27485
Total Area	-0.10611	0.46135*	-0.30398	-0.24463	0.3145
Total mgQCT	-0.12924	0.46772*	-0.2777	0.1536	0.41921
Trabecular Density	0.00155	-0.14161	-0.39778	-0.53831*	-0.37174
Trabecular Area	0.14847	-0.23063	-0.04896	-0.40035	-0.29847
Trabecular mgQCT	0.13612	-0.26396	-0.09783	-0.4433*	-0.33921
Cortical Density	0.21998	-0.35731	-0.11085	-0.40747	-0.42158
Cortical Area	-0.12259	0.42738	-0.06314	0.34913	0.44401*
Cortical mgQCT	-0.09348	0.41136	-0.13627	0.29485	0.41287
Breaking Strength	0.14419	0.13016	-0.32941	-0.06671	0.0251
Humerus					
Total Density	-0.15469	0.01794	-0.26285	-0.09038	-0.11528
Total Area	0.17792	0.45086*	-0.18163	-0.09432	0.27366
Total mgQCT	-0.12729	0.12226	-0.2776	-0.10506	-0.05083
Trabecular Density	----------	---------	--------	--------	--------
Trabecular Area	0.24198	0.32798	-0.075266	-0.08863	0.20559
Trabecular mgQCT	----------	---------	--------	--------	--------
Cortical Density	0.38683	-0.13547	-0.07142	-0.02013	-0.23836
Cortical Area	-0.22213	0.19719	-0.21923	-0.0688	0.05349
Cortical mgQCT	-0.08653	0.15147	-0.23856	-0.07653	-0.01763
Breaking Strength	-0.00818	0.13129	-0.30717	-0.06909	-0.03015
Tibia					
Total Density	0.05463	0.21928	-0.13581	0.2015	0.24496
Total Area	-0.04175	0.07985	0.12247	-0.0083	0.10915
Total mgQCT	0.01856	0.30506	-0.07844	0.21865	0.34754
Trabecular Density	0.12864	-0.16043	0.20211	0.03963	-0.10235
Trabecular Area	0.04993	-0.3086	0.09541	-0.2312	-0.35167
Trabecular mgQCT	0.07448	-0.34261	0.9468	-0.23443	-0.37573
Cortical Density	0.10584	-0.2919	-0.1574	-0.3869	-0.42862
Cortical Area	-0.03496	0.30891	0.07003	0.37972	0.41186
Cortical mgQCT	0.00611	0.29843	-0.01821	0.30657	0.36321
Breaking Strength	0.22079	0.04887	-0.33141	-0.13174	-0.06736

Table A.5 Correlation coefficients (r) for bone quality measures and indices of egg production or quality for MOD treatment birds _(*P <0.05)._

Bone quality Measure	Hen-day Production	Stored Egg Weight	Specific Gravity	Eggshell Thickness	Eggshell Weight
Femur					
Total Density	-0.01312	-2.7116	0.16165	-0.1292	-0.17375
Total Area	-0.05815	0.30499	-0.03934	0.09366	0.31374
Total mgQCT	-0.04794	-0.1049	0.11051	-0.09316	-0.02099
Trabecular Density	0.37781	0.067	-0.35229	-0.11673	-0.03404
Trabecular Area	0.04038	0.35433	-0.09898	0.23283	0.28992
Trabecular mgQCT	0.13556	0.3084	-0.1414	0.16953	0.25126
Cortical Density	0.09383	0.30884	-0.14646	0.19444	0.25432
Cortical Area	-0.12405	-0.19526	0.17501	-0.11275	-0.10944
Cortical mgQCT	-0.11431	-0.14681	0.17518	-0.07469	-0.05704
Breaking Strength	-0.04908	-0.16258	0.04295	-0.22579	-0.13398
Humerus					
Total Density	0.23546	-0.16408	0.06844	-0.00487	-0.03723
Total Area	-0.02843	0.10038	-0.28112	-0.33654	-0.14306
Total mgQCT	0.20979	-0.09283	-0.1052	-0.20178	-0.10107
Trabecular Density	----------	---------	--------	--------	--------
Trabecular Area	-0.0507	0.0823	-0.27277	-0.33047	-0.15795
Trabecular mgQCT	----------	---------	--------	--------	--------
Cortical Density	0.39931	-0.30161	0.14758	0.01469	-0.15085
Cortical Area	0.12788	-0.07055	0.01783	-0.04888	0.01798
Cortical mgQCT	0.22319	-0.14276	0.05526	-0.03534	-0.02878
Breaking Strength	0.27659	-0.10304	0.03995	0.03291	0.02402
Tibia					
Total Density	0.03194	-0.3354	0.13192	-0.1459	-0.21048
Total Area	0.06358	0.52914*	0.22112	0.40003	0.52637*
Total mgQCT	0.05477	-0.10736	0.19265	-0.01608	0.01109
Trabecular Density	0.13107	0.06445	-0.26529	-0.15764	-0.07201
Trabecular Area	0.05559	0.45174*	0.00569	0.33203	0.39264
Trabecular mgQCT	0.14505	0.40423	-0.07281	0.24553	0.33529
Cortical Density	0.11862	0.2669	-0.07232	0.21304	0.26807
Cortical Area	-0.04355	-0.20768	0.17779	-0.08767	-0.11017
Cortical mgQCT	-0.00867	-0.16652	0.20992	-0.02922	-0.04114
Breaking Strength	0.06347	-0.06531	0.17456	-0.02366	0.04664