Assessment of Laying Hens Maintained in Different Housing Systems

A report for the Australian Egg Corporation Limited

by G.D. Stewart, C. Rudkin, S. Shini and W.L. Bryden

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Researcher Contact Details

Name:	[Dr G.D. Stewart]
Address:	[School of Animal Studies, University of Queensland, Gatton 4343]
Phone:	[07 5460 1417]
Fax:	[07 5460 1444]
Email:	[geoffrey.stewart@uq.edu.au

In submitting this report, the researcher has agreed to AECL publishing this material in its edited form.

AECLContact Details:
Australian Egg Corporation Limited
A.B.N: 6610 2859 585
Suite 4.02, Level 4, 107 Mount St
North Sydney NSW 2060

Phone:	02 9409 6908
Fax:	02 9954 3133
Email:	irene@aecl,org
Website:	http://www.aecl.org

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Foreword

There is a widely held public perception that the welfare of hens used for the commercial production of eggs could be improved. Many consider that alternative housing systems such as free range and barn offer significant welfare advantages over cage systems. However, from published literature, it is difficult to make objective comparisons between different laying systems. Most scientific papers refer to experiments which relate to a particular housing system at a particular location, and few have been able to compare different housing systems at the same time. Therefore, scientific data is needed to enable producers, consumers, scientists and legislators to assess the advantages/disadvantages of different egg production systems.

In Australia, there have been no studies where replicated flocks have been housed in all the major conventional and alternative systems concurrently at the one geographical site. For this reason a facility for layer management has been established on the Gatton Campus of the University of Queensland. The facility is unique as all the major housing systems (free range, barn, conventional cages and controlled environment cages) have been developed at the one site to study welfare and production of flocks housed in each housing system simultaneosly.

The first flocks were housed during 2003-2004. Layers placed under five different conventional and alternative systems were monitored for welfare, production, and egg quality. This report entitled 'A*ssessment of Laying Hens Maintained in Different Housing Systems'* covers the results of the initial laying cycle in the newly established facility at Gatton.

This project was funded from industry revenue which is matched by funds provided by the Federal Government.

This report is an addition to AECL's range of research publications and forms part of our R&D program, which aims to support improved efficiency, sustainability, product quality, education and technology transfer in the Australian egg industry.

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David Witcombe
Program Manager R&D
Australian Egg Corporation Limited

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Abbreviations

BW	body weight
Ca	calcium
cm	centimetre
CP	crude protein
Cys	cystine
FCR	feed conversion ratio
g	gram
g/b/d	grams per bird per day
h	hour
HHP	hen housed production
Kg	kilogram
ME	metabolisable energy
Meth	methionine
min	minute
mm	millimetre
Na	sodium
ng	nanogram
P	phosphorus
s	second
wks	weeks

Executive Summary

This report presents the results of the initial flocks of hens housed concurrently under conventional and alternative housing systems currently operating in Australia. The assessment of welfare, behaviour and production of hens housed in five housing systems was conducted at the University of Queensland Gatton, Poultry Research Unit.

From 19 to 70 weeks of age three replicates of each housing type (free range, barn, conventional cages and controlled environment cages) were assessed. All birds were reared under the same housing type as their laying conditions. The diet and management were comparable for all different housing systems taken under assessment. Free-range system was represented in this study by three separated units (replicates) located adjacent to each other with 600 hens per replication. This system provided a density of 1500 hens/hectare in the range, and 5 hens/m2 of floor space in the shed. Nest boxes, perches, feed and water were available in the house and birds have had access to a grassed outdoor free-range area. Hens in the barn system were housed in one insulated shed separated into three units, with 600 hens for each replicate and a density of 5 hens/m². The barn system offered access to ground or floor space, automated feeding and drinking systems, perches, and stepping rails to automated egg collection nest boxes. Hens maintained in the conventional cages (*Euro-vent* style, Big Dutchman International GmbH) were located in a controlled environment, where house temperature was maintained at approximately 24°C. This system was presented by a traditional 3-tier cage system in two rows, back to back, with 3 replicates x 18 units x 6 hens per cage, and a density of 550cm2/bird. The conventional (Australian) cage systems were located in open-side sheds, with 3 replicate x 18 units of six hens per cage and 3 replicate x 18 units of three hens per cage, both at the same density of 450cm2 per bird.

The effects that five different housing systems show on the production, physiology and behaviour of laying hens were examined to collect comprehensive set of data relating to production and welfare. However, in interpreting the results of this assessment it should be noted that there have been different implications during the laying cycle that may have influenced the results. Of importance were:

- an acute outbreak of Egg Drop Syndrome (EDS) in all flocks just after point of lay which reduced peak production and consequently affected total production;
- an outbreak of cannibalism in the barn flocks at 47 weeks of age. Therefore it was decided that all the barn birds should be beak trimmed to stop further injury to the birds. This 'mid-lay' beak trimming effected on mortality, hen day production and daily feed consumption. Although the beak trimming stopped the cannibalism, egg production did not return to pre-cannibalism levels; and
- a significant heat wave (ambient temperature reached ca. 42°C in the shed) at around 61 weeks of age. The 2003/2004 year occurred in part of the longest drought in recorded history for the Gatton area and ambient temperatures were also extreme. During the heat wave the ambient air temperatures increased to +45ºC. As a result birds in cages without controlled environment had decreased production and increased mortality over a period of approximately four days.

Results of this study showed that, as regard to production, physiology and behaviour, the conventional 3 bird/cage system appeared to function better under Australian conditions. During 52 weeks of laying birds in 3 hens/cage achieved an average hen housed production (HHP) of 76%, whereas birds in other systems (free range, barn, controlled environment cages and conventional cages 6 hens/cage) HHP was 67%, 60%, 67% and 68%, respectively. Hens in 6 bird/cage system have also showed better parameters of production than hens in free range, though the health and physiological indices of hens in free range were better than caged hens. As compared to all conventional cages and alternative housing systems, controlled environment cage system did not show any specific positive influence on egg production and welfare of birds. Nevertheless, the shed temperature was controlled this did appear not to help hens to cope with their environment and

perform better. Interestingly, in all, the results made evident that hens in free range were capable of similar performance as hens in cage system, while demonstrating better indices of health and welfare. In contrast, hens in barn exhibited lower than average production.

Albumen corticosterone concentrations indicated that the drop in corticosterone concentrations at 70 weeks of age compared with that at 35 weeks of age in all flocks suggested that birds adapt better (or are less stressed by their macro and micro environment) as they get older, whatever the housing system was. This did not happen with H/L ratio which also was used as an indicator of stress. Total and differential white blood cell counts were altered differently at different measurements (33 and 63 weeks of age), suggesting alteration of the cell response due to stress and/or bacterial infection. As known white blood cells may be affected by a variety of factors/stressors which consistently elevate the heterophil/lymphocyte ratio (Gross and Siegel, 1981, 1983), although other external and internal invaders may affect these cells as well. At 33 weeks of age H/L ratios of birds housed in the barn system showed that they had been exposed to some degree of stress. Clearly, factors such as large flocks, overcrowding and a barren environment in the barn system presumably induced stress (around 33-35 weeks of age) that subsequently were manifested by an aggressive behaviour (cannibalism outbreak at about 40 weeks of age) in hens. Furthermore, on the end of lay hens in barn hens showed a significant increase in total albumen corticosterone concentrations (51.8ng) and mortality (ca. 34%), but not H/L ratio (0.43). The presence of microbial agents in alternative housing conditions such as barn system might have been the reason why heterophils were increased at the start of lay. After birds have acquired their immunity against bacteria the number of hetrophil cells was stabilised. A sufficient number of circulating leukocytes in appropriate proportion is essential for hens to produce an immune response against. However, an increase in H/L ratio does not always indicate the presence of stress, though microbial agents are considered to be stress factors per se.

As expected exercise was highly correlated to bone strength and consequently, free range and barn birds have had stronger femurs than similar birds housed in cages. Those housing systems which allowed for unimpeded ability for the birds to flap and stretch their wings and to use their wings for jumping/flying without impedance resulted in the strongest humeri.

Behaviour results showed that most of behaviours were similar at mid- and end-of-lay. The larger conventional (6 hens/cage) and controlled environment (*Euro-vent*) cages gave more freedom of movement to the hens than the smaller (3 hens/cage) conventional cages. However, hens in 3 hens/cage did not appear to be restricted in their use of different parts of the cage as compared to the hens in the larger (6 hens/cage) cages. Hens in the barn and free range used their extra space to walk about more than hens in cages, they were able to move freely about their enclosures, and were about equally distributed between floor and slats in barns, and inside and outside the shed in free range. Hens in free range fully used their perch space at night, and few non-laying hens occupied the nests. Hens in both barn and free range occupied perches less than 10 percent of the time during the day. Barn hens preferred to perch on the metal bars over their food rather than the slats at night, with those that did not fit on the perches distributing themselves about the enclosure, including nests. The behaviour rates of feeding, standing, ground pecking, scratching, walking, and feather pecking indicated that the extra stimuli provided by barn and free range were at least partially successful in directing behaviours away from non-feeding pecks at food and feather pecking.

As regard to feather scoring hens in cages tended to have similar amount of damage over the whole of each body part, while hens in barn and free range tended to have some areas of each body part completely bare, while other parts were well feathered. The time that free range hens spent outside did not seem to affect feather pecking. Judging by foot condition, the alternative housing and all cage types were reasonably comfortable for the hens. All feet examined were only mildly calloused, with no extensive damage. In particular, the feet of hens housed in controlled environment cages were less callused, but claws on the outer toes were sometimes broken. These hens were observed often leaning this toe against the edge of the cage while feeding. Nearly all hens in the conventional cages (3 birds/cage and 6 birds/cage) showed some damage to feet, while only just over half of hens in controlled environment cages had some damage, indicating that the floors of these newer cages has been more comfortable than the older style cages. The claws of all caged hens were sharp which could have been a problem when hens stood on one another. No hens examined had bumble-foot, so the perches were of a suitable design. The free range hens had very well worn claws, perhaps due to the nature of the substrate rather than due to more scratching as their scratch rates did not differ significantly.

In conclusion, parameters of performance, physiology and behaviour were of greater importance in assessing different housing systems. Conventional and alternative housing systems showed different effects on hen production and welfare, though within biological, nutritional and environmental limits hens seem to produce at a comparable level. This implies that the physiological mechanisms that underpinned the neuroendocrine-immune response could be altered to maintain homeostasis. It should be noted that different housing systems offered hens different ability to respond to their environment, so that the most important activity for laying hens, egg production was maintained, while health and welfare might have been compromised.

1. Introduction

1.1 Background

There is both an egg consumers' and a retailers' perception that there is wide variation in the health and welfare of hens housed in the various egg production systems (barn, free range, and cages).The welfare of commercial egg-laying hens has long been an issue of debate. In Europe, North America and Australia, there have been important changes in laying hen management to improve bird welfare. Poultry producers are now more aware of the cost of inadequate management in terms of the potential loss of productivity and reduced bird welfare. In fact, in 1990 the Australian Senate recommended a consideration of the banning of laying cages once viable alternatives with welfare advantages and suitable to Australian conditions are developed (Australian Government Department of Agriculture, Fisheries and Forestry, 2004). Currently, approximately 9% of hens are housed in range systems, 6% are in barn systems and 85% of hens are housed in cages in open sided or controlled environment sheds (AECL, 2006).

There has been a considerable research into on non-cage housing systems with a major emphasis being the solving of practical problems rather than developing understanding of some of the principles through a systematic scientific approach. While this may be understandable because of the apparent urgency and the expense and time involved in researching non-cage systems, the result is insufficient data to draw rigorous conclusions. Nevertheless, there is considerable support for non-cage systems, in part on the basis of the increased behavioural repertoire they permit for the hen (Tanaka and Hurnik, 1992) and lower levels of fear in the tonic immobility test (Hansen et al., 1993). A number of alternative systems, including details of economics, advantages and disadvantages, are described in Kuit *et al.* (1989). Some of the components of the non-cage systems have been systematically studied are bone strength, egg quality and behaviour. For example, it is generally agreed that bone strength is improved in non-cage systems (McLean et al., 1986; Knowles and Broom, 1990; Norgaard-Nielsen, 1990; Gregory et al., 1991), although it has been identified that all systems with perches result in keel bone deformation (Engstrom and Schaller, 1993; Abrahamsson and Tauson, 1995). Eggshell defects are generally more common in eggs from alternative production systems (Bain, 1992; Van Horne 1994; Fraser and Bain, 1994). While it has been shown that hens prefer to congregate with familiar rather than unfamiliar birds (Bradshaw, 1992), the relevance of this to welfare and housing design is unknown. Other aspects that have been or are being studied are spacing between perches (Scott and Parker, 1994), space allowances for different behaviours (Keeling, 1994) and rearing conditions (Hansen and Braastad, 1994). Studies that have assessed conventional and alternative housing systems provide mainly behavioural data. Behaviour rates of birds in cages, aviaries, modified litter systems, and semi-natural conditions have been reported by Nicol 1987, Appleby *et al.* 1989, Dawkins 1989, Braastad 1990, Hansen 1994, Keeling 1994, Barnett et al., 1997, Hocking et al. 1997, Rudkin 1998, Rudkin and Stewart, 2002. Most of the studies that used behaviour as an indicator of welfare also included feather and body scores as a measurement to be assessed.

In summary, there is a lack of comprehensive scientific information available to all sectors of the egg industry to explain their practices and provide accurate information for consumers about each production system. Data is urgently needed to enable media and educational specialists to properly inform the public about the advantages/ disadvantages of each production system. The consumers need to be able to make an informed choice of the eggs they wish to buy whether this choice is based on a single issue such price, welfare of hen or food safety or a combination of these issues.

1.2 Establishment of a National Laying Hen Research Facility

A facility for layer management research has been established on the Gatton Campus of the University of Queensland. This research facility is unique in providing on a single site commercial scale models of all of the four main production systems currently being used commercially in Australia i.e., free range, barn, naturally ventilated and environmentally controlled cage laying systems. A detailed description of the facility and the experimental design of the research are presented in Chapter 2.

1.3 Industry interaction

A National Industry Advisory Group for Layer Housing was formed to provide critical advise on the conduct of the project. The National Industry Advisory Group met on two occasions during the first year at UQ Gatton to review progress and to make recommendations for future research. The Advisory group included representatives from the Commonwealth Department of Primary Industries, the Australian Egg Corporation Ltd., the Free Range Egg Producers Association and the Royal Society for the Prevention of Cruelty to Animals (RSPCA); the latter has been chosen because of its strong support for barn hen production and for its critical interest in animal welfare generally and commercial egg production in particular.

1.4 Research collaboration

This project involved participants from the University of Queensland, the University of New England, and the University of Sydney.

1.5 Objectives

The aim of the project was to assess the performance, egg quality, health and welfare of laying hens housed in the different housing systems: free range, barn, cages in environmentally controlled conditions, and cages in naturally ventilated conditions. Some of the objectives were:

- to evaluate production and hen welfare in different housing systems
- to provide evidence of strength and weakness of each housing system
- to make specific recommendations for the laying hen industry

The long-term goal of this research is to contribute into improving of both the management of layer housing systems as they operate under Australian climatic conditions and hen welfare.

1.6 Animal ethics

Experimental procedures described in this report which involved the use of birds were approved by the University of Queensland Animal Care and Ethics Committee (Approval No. SAS/050/03/RIRDC) and complied with the *Australian Model Code of Practice for the Care and Use of Animals for Scientific Purposes*.

2. Materials and Methods

2.1 Birds

ISA Brown 2000 pullets, were hatched and reared in accordance with commercial practice in systems appropriate for the layer housing system to which the bird were allocated at 19 weeks of age. During rearing birds were vaccinated for Fowl Pox, Mareks Disease, Newcastle Disease, Infectious Bronchitis, Infectious Laryngotracheitis (ILT), Avian Encephalomyelitis and Egg Drop Syndrome. All cage birds were beak trimmed but free range and barn pullets were not.

Birds were fed *ad libitum* throughout the trial. The feed was produced at the University feed mill and met the following specifications: CP - 17.5%; ME – 11.3 MJ/kg; Ca – 4.0%; available P – 0.7%; Na – 0.18%; Lysine – 0.85%, Meth. + Cys.– 0.77%.

A standard 16 hour lighting program was used (on 0400hrs – off 2000hrs). Welfare check was done on all flocks as the first chore each day and any dead or sick hen recorded and removed. The performance recording period for all flocks in all systems was from 19 weeks of age to 70 weeks of age (a complete 52 week laying cycle).

2.2 Housing

The facilities used in this study were established over a number of years after detailed discussions with various segments of the poultry industry. The final configuration of the housing systems involved the erection of new facilities and the adaptation of existing buildings within the Poultry Unit on the Gatton Campus of the University of Queensland.

2.2.1 Conventional cages (3 hens/cage)

Conventional Australian cages (3 hens/cage) were located in a traditional sawtooth design open-side shed (Figure 1), fitted with two temperature controlled blower fans set to operate when the temperature reached 28°C. The cages used were standard 3 hen cages (30cm x 45cm), which allowed 450 cm^2/bird unrestricted floor space (Figure 2) as recommended in the current *Model Code of Practice – Domestic Poultry*. Approximately, 60% of the Australian layer industry still uses this type of cage. The cages were in a single tier, above a concrete floor. Cage floor slope was estimated to be 8° and eggs rolled out onto an egg tray along the front of the cages where the eggs were manually collected. Feed troughs in front were manually replenished and water was provided by nipples along the back of the cages. Hens in each cage could access two water nipples. The flock was represented by 162 birds divided in three replicates with 18 cage units each.

Figure 1. Conventional sawtooth shed

Figure 2. Conventional cages, 3 hens/cage

2.2.2 Conventional cages (6 hens/cage)

The conventional cages (6 hens/cage), originally a standard 3 hen cage were modified so that each expanded cage (measured 60cm x 45cm) would allow for the placement of 6 hens at a density of 450 cm2/bird. The shed was part of a gable type shed with two divisions under a single insulated roof. Twenty five percent of the shed was occupied by conventional cages, while 75% of the shed was used for conventional '*Euro-vent* 550' cages. The conventional shed was an open-side naturally ventilated shed (Figure 3). The cages used were above a concrete floor; cage floor slope was in a range from 6° to 11°. Feed troughs in front were manually replenished and water was provided by nipples along the back of the cages. Hens in each cage could access two nipples. There were three double rows of cages (Figure 4) with the two rows in each double row being back to back. Each double row constituted a replicate. Birds (324) were divided in three replicates that constituted of 18 cage units.

Figure 3. Conventional laying shed (gable type)

Figure 4. Conventional cages, 6 hens/cage

2.2.3 Controlled environment cages

The conventional *Euro-vent* 550 cages were located in an environmentally controlled shed, which was the original gable type shed (Figure 5). Extractor fans controlled the temperature automatically by drawing air through the batts and maintaining the temperature at approximately 24°C; water soaked batts forming an end wall. Cages (Figure 6) were in three tiers in double rows with cages back to back and had solid sides, and wire backs and floors. The floor slope of cages was 7°. A plastic belt under the cages collected droppings which were mechanically moved to the end of the shed where the belt was cleaned. The feed trough was automatically replenished with feed, but as individual feed consumption was measured, the troughs are manually replenished from weighed holding bins. Eggs were manually collected from the egg trays in front of the cages. Water was available from 2 nipple drinkers/cage. Each cage housed 6 hens at a density of 550 cm2/hen satisfying standards for cages installed after 2001 as specified in the '*Australian Model Code of Practice for Welfare of Animals – Domestic Poultry 4th Edition'* 2001.

For data analysis, cages were assigned to three replicates with 18 units each, making in total 54 units or 324 birds. To analyse row effects, rows were numbered from 1 to 6 with numbering starting from the bottom row moving over the top, and ending at the bottom row on the next side.

Figure 5. Controlled environment shed

Figure 6. Conventional *Euro-vent* 550 cages

2.2.4 Barn system

The barn system was represented by three separate barn flocks housed under one roof (Figure 7). The barns were built according to published RSPCA Australian Standards. Each barn flock measured 11x12m and houses 600 birds (at approx. 7 hens/m²) (Figure 8). A service walkway run full length down the southern wall. Along the length of each barn was a double central row of roll-away nests, each row back to back. The total length of the nests was 895 cm with six nests (150x50 cm) on each side. Each nest was lined with a soft plastic material similar to plastic lawn, but with a higher pile. The nest floor slopes towarded the back of the nest so that the eggs from the nests on each side rolled out onto a central belt, which could then move them to a collection point at the end of each barn. The nest floors were able to be automatically raised at night so that hens could not spend the night in the nests. On each side of the nests, flockss provided an area of raised plastic slats (2.4 m wide??), over a manure pit and an area of litter floor (2.3 m wide??). The plastic slats had lines of thicknesses along them and were designed to act as perches so that hens can close their toes about them. A water line with cupped nipples and a feeder line (2956 cm, making feeder space/hen 4.9 cm) was provided on each slat area. A metal bar 15 cm above the feeder line formed a perch and prevented hens from standing in the feed. The floor area consisted of a concrete floor covered by litter (wood-shavings).

Figure 7. Laying shed containing three barn flocks.

Figure 8. Internal view of a barn flock showing litter and slatted floors, drinkers, chain feeders and colony nests and boxes.

2.2.5 Free range

Free range facility was represented by three separate free-range sheds in separate enclosed yards (or ranges) adjacent to one another designed in collaboration with the Australian Free Range Association. The system provided a density 1500 hens/hectare in the range, and 5 hens/m2 of floor space in the shed in accordance with the *Australian Model Code of Practice for Welfare of Animals – Domestic Poultry 4th Edition'* 2001 (Figure 9). Thirty-six rows of wooden perches, 55 cm high, and each 3 m long occupied the centre of each shed (Figure 10). This provided 176 mm of perching space/bird. An automatic feeder line (giving a space of 4.8 cm/hen), with a metal perch bar above it, encircled the perches, and a water line with cupped nipples run down the length of the shed on each side. Three banks of nests occupied the wall on the south side, and one bank of nests occupied the end wall on the west side of the shed. Each bank contained 12 wooden nests down its length, and 5 rows of nests above one another, giving 128 nests in all. Each nest measured 30cm^3. Wooden perches in front of the nests at various heights allowed hens to easy access the nests. The nests were lined with wood shavings which were regularly replenished to keep the nests clean. The shed had a roller door and a door at the east end of the shed, and two doors on each side. Only the two doors on the north side were opened during the day, All doors were closed after dark to protect the hens from predators. At the placement of pullets the rages were covered in grass.

Figure 9. The free range facility showing three shed and associated ranges

Figure 10. Lay out of the free range shed showing nest boxes, perches, nipple drinkers and chain feeders

2.3 Production parameters

Assessment of production performance included the following parameters: egg production, egg weight, feed consumption, body weight, and mortality. The number of eggs laid in a flock between weeks 19 and 70 is given as a percentage in the hen day production (HDP) and hen housed production (HHP) parameters, where hen is the number of hens alive in the flock at a specific day over the whole observation period. HHP gives the performance of the flock over the full laying cycle as it takes mortality into account, while number of eggs per hen housed per day is a cumulative count of egg production based on the original number of hens housed and allows for easy comparison between flocks of similar age.

Mortality rates (cumulative) for all systems were calculated on the end of the 70 weeks of age and were expressed as a percentage of hens initially housed to the number of hens which died.

Feed intake (g/bird/day) was measured during the experiment and feed conversion ratio (FCR, g/g) was calculated as the mean of feed intake per mean of egg weight collected during the experiment:

FCR=g feed consumed/g egg produced

Body weight was determined by weighing fifty birds from each flock in the free-range and barn systems, and all birds in each cage from half of all cages in each cage system.

Eggs were collected daily between 09:30 and 12:30. Egg production, mortality and feed consumption were measured on a continuous basis throughout the laying year. Body weight was measured monthly.

2.4 Egg quality and bone strength

Egg quality and bone strength (breaking strength of humerus and femur) analyses were performed at the Poultry Research and Teaching Unit, University of New England (Roberts and Ball, 2003). Thirty samples from each replicate were taken for analyses.

Egg quality was monitored at both 35 and 70 weeks of age, while bone strength was assessed at the end of the laying period.

2.5 Physiological parameters

2.5.1 Differential leukocyte counts and H/L ratios

Differential leukocyte counts and H/L ratios were determined twice, at the peak of lay (33 weeks of age) and towards the end of lay (at 63 weeks of age). For haematological analyses 36 birds from each system were chosen at random. To obtain a blood leukocyte profile and to determine the H/L ratio the stained-slide-method was used (Campbell, 1995). A blood smears for each hen were prepared immediately after blood collection and fixed with methanol. Smears were stained with Wright's and May-Grünwald stains, rinsed with distilled water and were allowed to air dry. Cells per slide were counted (100/slide) and classified using oil immersion microscopy at 1000X. Differential leukocyte counts included heterophils, lymphocytes, eosinophils, monocytes, basophils (expressed as percentages of total leukocytes) and the H/L ratio was calculated as a ratio of percentages of heterophils to lymphocytes for each hen sampled.

2.5.2 Egg albumen corticosterone concentrations

Egg albumen corticosterone concentration was measured at 35 and 70 weeks of age. Egg albumen corticosterone concentrations were determined by radioimmunoassay (RIA) as described by Downing and Bryden (2002), and performed at the Poultry Research Unit, University of Sydney.

2.6 Behavioural observations

Data was collected in a fully randomized manner with birds being observed in a random order at a random time of day. Observations were performed at approximately 36 weeks of age, and at approximately 65 weeks of age. Hens were identified with a colored plastic leg band and no hen was observed more than once. Observers took care to wear familiar clothes and move quietly when near hens to disturb them as little as possible. Each focal bird was scan sampled for five minutes. This consisted of noting:

- *position* (including front or back of the cages; floor, slats, perch or 'other' in the barns; and floor, floor under the perches, wooden perch, and metal perch in the range);
- *activity* (including: feeding, head out, drinking, preening, sitting, and standing), and
- *incidents of stereotypies* (such as, beak pecking, feather ruffling, stretching or dust-bathing). When hens in the free range system were outside, it was noted whether the hen was in the sun or shade, and whether incidents of aggressive interactions or feather pecking occurred.

Percentages of scans when birds engaged in each activity or position were then calculated. The likelihood of such an interaction occurring in a five minute observation period was then calculated. In all, behavioural observations were made of hens for 15 hours for each system.

2.7 Feather and foot condition

Hens were assessed for feather condition at 70 weeks of age. Fifty hens were randomly selected from each of the barn and range replicates; all hens were scored in conventional cages; 30 hens were randomly selected from each of the six rows of conventional cages; and all hens were scored in environmentally controlled cages. Each of six body parts were scored: neck, back, tail, wings, sides, and abdomen (Appleby and Hughes, 1995). Feathering was scored according to four criteria: area of total damage, area of worst damage, degree of worst damage, degree of other damage. Each was scored out of five, making the total possible score of 20 for each body part, and 120 for each hen. Data were calculated as a percent of total possible score and presented as total scores; and total scores for each body part.

The right feet of the sampled hen from each system were examined for claw length and foot damage. The claws were measured from the base to the tip, and no attempt was made to follow the curvature of the claw. Extent of damage was estimated by a predetermined scoring method. Each foot was scored out of three: 0, no damage; 1, some callusing; 2, more extensive callusing or some damage; 3, severe damage.

2.8 Statistical analyses

For production and physiological parameters statistical analyses were undertaken using SAS/STAT software, version 6.12 of the SAS System for Windows (SAS Institute Inc., 1996). Data were subjected to analysis of variance with “housing” as the main factor. Flocks were treated as independent units. Mean values for production data and physiological variables were calculated for each flock. Significant differences among systems were determined using Pearson’s correlation coefficient.

To make it possible for statistical analysis behaviour rates and position changes were converted to percent behaviour rates and changes. Feather pecking and aggression, were converted to probability of an incident involving an animal occurring during a five minute observation period. Head out feeding or looking data were converted to a percentage of the total number of hens in each cage. The feather scores for each hen, or each body part, and for each type of damage data were converted to a percentage of the total possible score with highest score indicating best feathering. In almost all cases, analysis of variance (ANOVA) was found to be the most appropriate statistical method to assess effects of housing system on hen behaviour. Analyses were carried out using the General Linear Models procedure in the SAS System for Windows Version 8 (1999-2001). As replicates in each system were not randomly assigned, system differences were analysed using a nested model with replicates nested within each treatment. Least squares means for each system were compared using pair-wise t-tests. Age effects between mid- and end-of-lay were estimated using the Mixed Procedure in the SAS System for Windows.

3. Results

3.1 General observations

This trial is the first one completed in the new layer housing facilities. The pullets for the trial were reared by a commercial supplier 'off-site' on a single farm – so the disease status of the pullets delivered to the Gatton Poultry Research Unit were similar. The pullets were reared in facilities similar to their laying facilities (i.e. range pullets reared on range, cage birds reared in cages). It was not possible to rear pullets on-site to minimize the natural disease challenge associated with shifting birds from one farm and locality to another.

During the course of the laying cycle a number of events (see Figure 11) occurred over which the researchers had no control. These events which adversely effected production are outlined below.

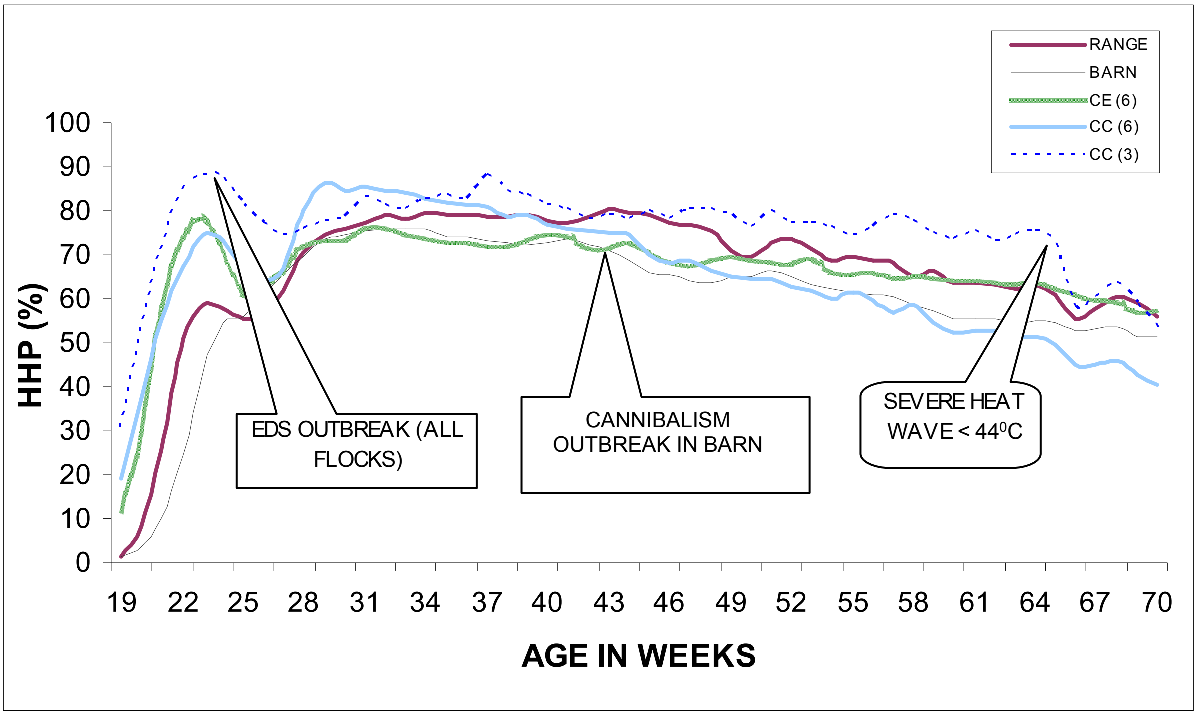


Figure 11. Average weekly hen housed production in all systems
Abbreviations: CE (6) – controlled environment (6 hens /cage); CC (6) – conventional cages (6 hens/cage); CC (3) - conventional cages (3 hens/cage)

The Egg Drop Syndrome (EDS) outbreak affected all flocks just after point of lay and reduced peak production and consequently affected total production. Although the pullets had been vaccinated for EDS, clinical signs of this disease were observed including a marked decrease in shell quality and a significant drop in production with no obvious respiratory symptoms, no nasal discharge, no eye discharge, and no significant increase in mortality. The flocks were not morbid. Serology showed that the blood titre was high for EDS across all flocks, but it could not be distinguished from the vaccination titre, and therefore an EDS outbreak could not be absolutely established. A number of major egg producers in South East Queensland reported a similar outbreak in their flocks at the same time as the Gatton outbreak.

An outbreak of severe cannibalism in the barn flocks increased mortality significantly and the subsequent ‘in-lay’ beak trimming affected hen day production and daily feed consumption. Although beak trimming stopped the cannibalism, egg production did not return to pre-cannibalism levels. The 2003/2004 year occurred in part of the longest drought in recorded history for the Gatton area and ambient temperatures were extreme.

During the heat wave the ambient air temperatures increased to +44ºC. As a result, birds in cages without controlled environment had decreased production and increased mortality over a period of approximately four days.

As mentioned above, this trial was conducted in new facilities in the free range, barn and controlled environment sheds and there had been no opportunity for the equipment to be flock tested prior to the commencement of this study. Consequently, there were husbandry/management adjustments which were required throughout lay to rectify minor problems that developed (e.g. fan speed, trough chain feed height, etc.)

3.2 Egg production and quality

3.2.1 Hen housed production

Figure 11 presents the average hen housed production (HHP) over the 52 week laying cycle, which shows that after reaching peak (week 33-35) there is a consistent trend of decreased production over time for hens from all housing systems.

As shown in Figure 12 there were significant differences (P<0.05) in HHP between housing systems. From 19 to 70 weeks of ages hens housed in conventional cages 3 hens/cage achieved the highest production (76.2%) while hens in barn had the lowest production (60%). Performance of barn hens was reduced by cannibalism. Figure 13 shows that the production was dropping because of the cannibalism but after the beaks were trimmed production continued to decrease for a week and increased thereafter. However, as noted above (Figure 11), egg production of barn hens did not return to pre-cannibalism levels after beak trimming.

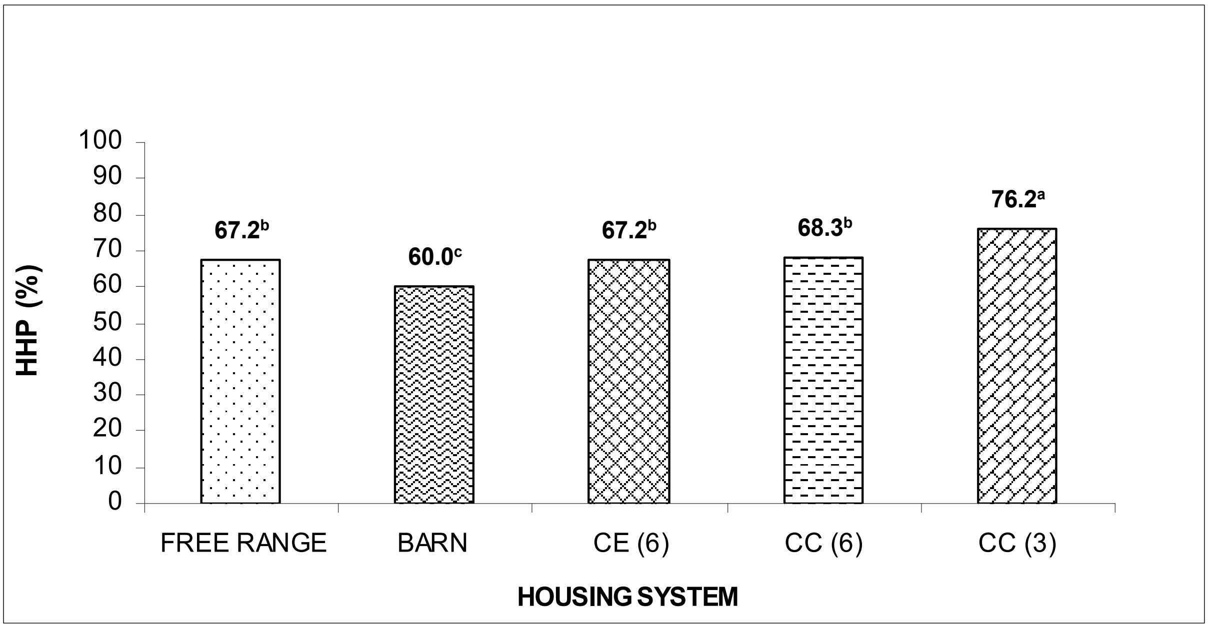


Figure 12. Average hen housed production (%) over the laying cycle in all systems

Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at *P*<0.05

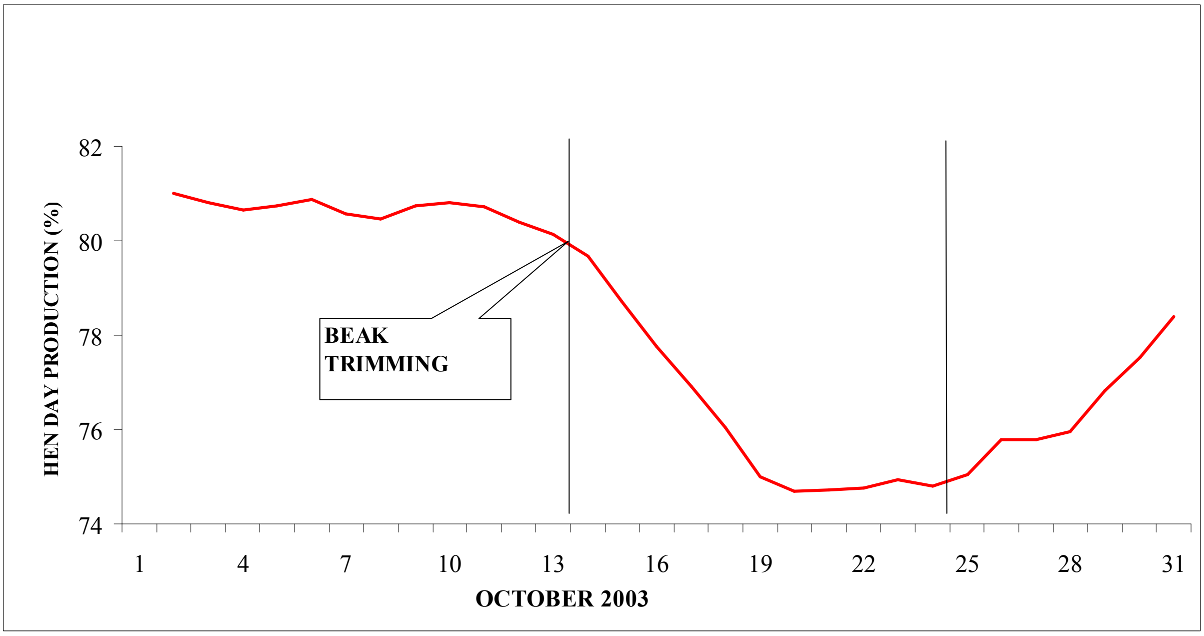


Figure 13. The effect of beak trimming at 47 weeks of age on hen day production in barn flocks.

3.2.2 Egg per hen housed

Data showing the average number of eggs produced per hen housed (Figure 14) demonstrates that hens in conventional cages (3 hens/cage) produced significantly ($P<0.05$) 20% more than hens in barn, and 10-12% more than hens in free range, conventional cages 6 hens/cage, and hens in controlled environment cages.

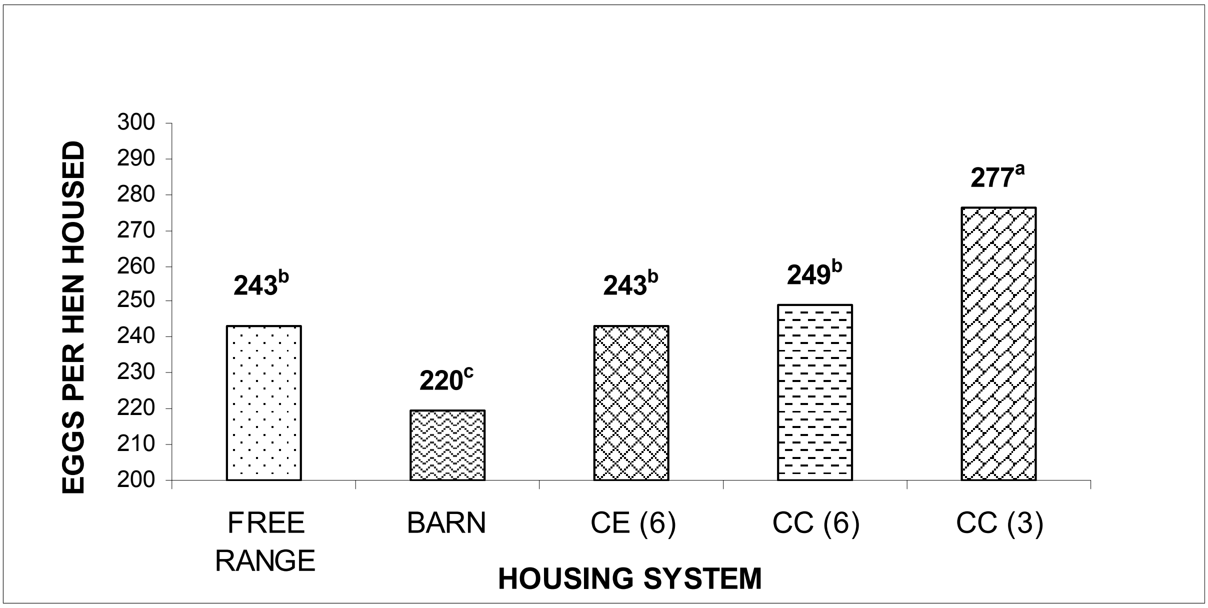


Figure 14. Average number of eggs per hen housed (52 weeks of lay) in all systems.
Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at $P<0.05$

3.2.3 Egg breakage

The percentage of broken eggs (Figure 15) in the barn system was significantly higher than in all other systems. It should be noted that broken eggs may be underestimated in barn and free range systems, as egg are often eaten by hens (including the shell) and hence are not recorded. In contrast, broken eggs in the cage systems are usually found in the cage roll-out trays and thus are counted.

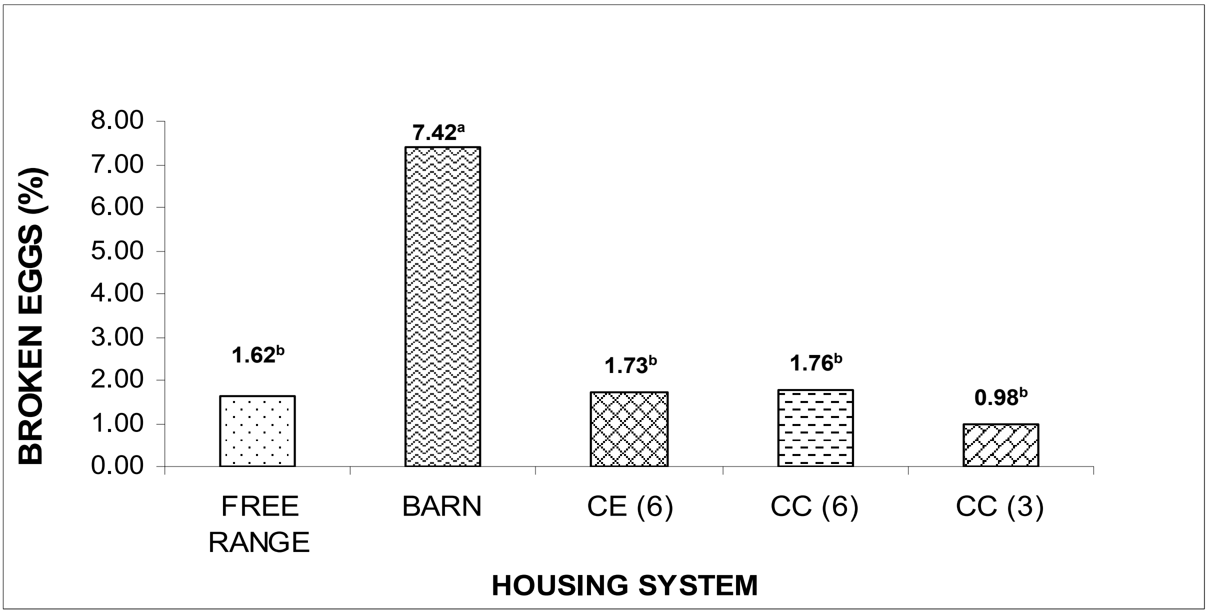


Figure 15. Percentage of broken eggs in all systems.

Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at $P<0.05$

3.2.4 Egg weight

Figure 16 presents results of egg weight for all housing systems. Average egg weight did not show any significant differences between systems. However, when expressed as egg mass/hen housed (Figure 17) hens in conventional 3 hens/cage were more productive than hens in all other systems. The average egg mass/hen housed provides an integrated picture of average productive egg output per hen housed by taking into account egg production, egg weight and mortality, therefore is a better indicator of flock performance.

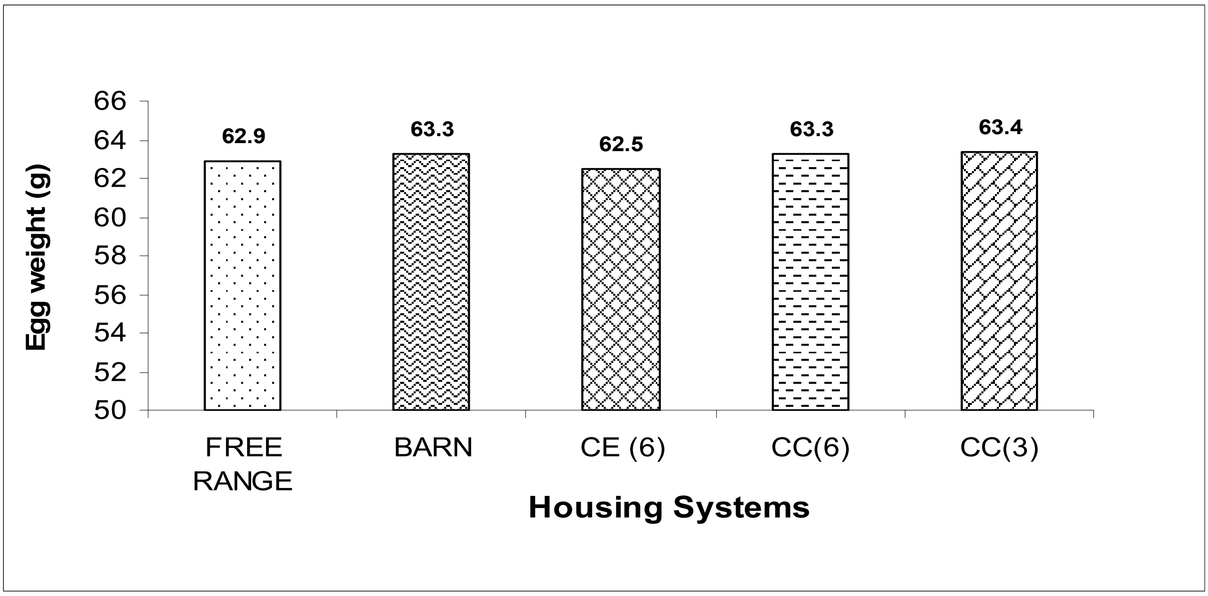


Figure 16. Average egg weight in all systems.
Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at *P*<0.05

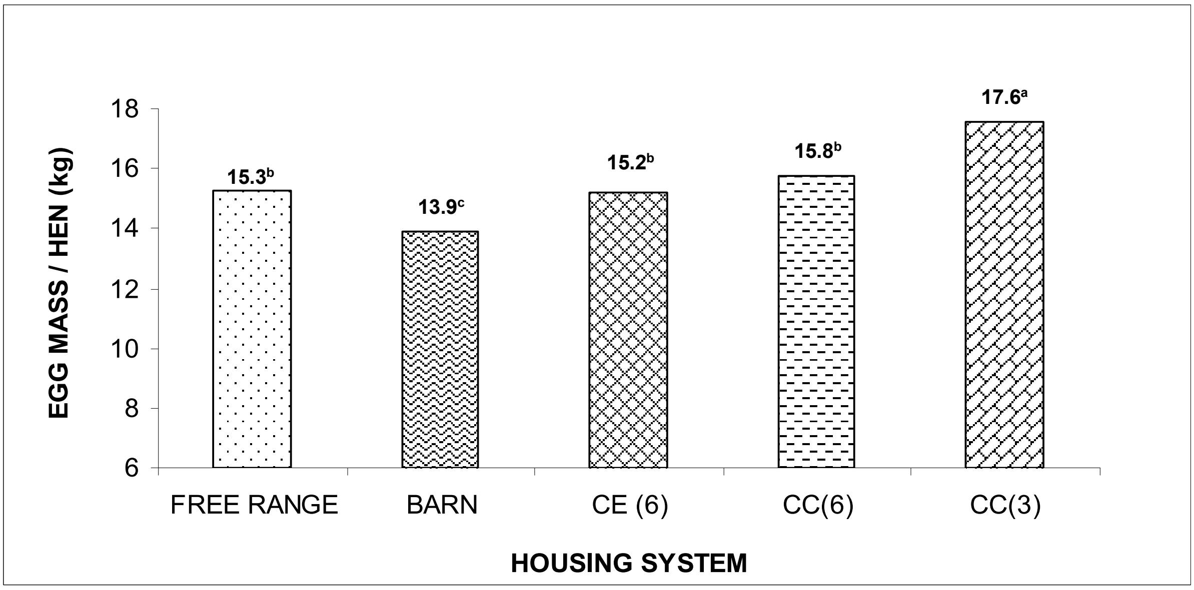


Figure 17. Average egg mass per hen housed in all systems.
Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at *P*<0.05

3.2.5 Egg quality

Results showing the effects of different housing systems on egg quality are presented in Table 1.

Table 1. Egg quality for hens in all systems measured at 35 and 70 weeks of age

Measurement	Housing system					
	FREE RANGE	BARN	CE(6)	CC(6)	CC(3)	P value
35 weeks of age						
Egg weight (g)	63.2^{a}	63.2^{a}	62.0^{b}	63.1^{a}	63.4^{a}	<0.05
Shell reflectivity (%)	36.0^{a}	32.4^{b}	33.4^{b}	32.6^{b}	32.4^{b}	<0.0001
Breaking strength (Newton)	40.3^{b}	40.9^{b}	37.9^{c}	44.6^{a}	41.8^{ab}	<0.0001
Deformation (µm)	272.3	280.8	263.3	280.8	285.7	0.25
Shell weight (g)	6.21^{b}	6.39^{a}	5.86^{c}	6.15^{b}	6.14^{b}	<0.0001
Shell % (% of egg)	9.82^{b}	10.11^{a}	9.46^{c}	9.75^{b}	9.71^{bc}	<0.0001
Albumen height (mm)	8.19	8.37	8.26	8.48	8.55	0.194
Haugh Units	89	89.9	89.7	90.8	91.2	0.147
Yolk colour	10.8^{a}	10.0^{c}	10.3^{b}	10.2^{bc}	10.4^{b}	<0.0001
70 weeks of age						
Egg weight (g)	66.24	66.18	66.7	66.51	65.24	NS
Shell reflectivity (%)	58.07^{x}	37.83^{y}	35.08^{z}	36.40^{z}	37.88^{y}	<0.0001
Breaking strength (Newton)	37.14^{xy}	35.47^{yz}	36.22^{xyz}	37.34^{x}	34.85^{z}	0.0264
Deformation (µm)	308.9	302.7	314.8	300.6	330.1	NS
Shell weight (g)	6.06^{x}	6.26^{x}	6.12^{xy}	6.22^{x}	6.13^{xy}	0.049
Shell % (% of egg)	9.17^{z}	9.47^{x}	9.19^{yz}	9.37^{xy}	9.41^{x}	0.0048
Albumen height (mm)	6.32	6.33	6.56	6.33	6.27	NS
Haugh Units	75.55	75.64	76.86	76.86	75.55	NS
Yolk colour	12.9	12.05	12.37	11.94	11.29	NS

Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at $P<0.05$

At both 35 and 70 weeks of age there were significant differences in shell colour (% reflectivity) between eggs from hens in different housing systems. At 70 weeks of age shell colour was clearly darker in eggs from free range hens as compared with eggs from all other systems. Shell breaking strength data also demonstrated that there were significant differences between systems (lower at cages) at either age and there was a tendency for breaking strength to be lower as birds age. Data on shell deformation, indicated no significant effects of housing systems, however deformation increased with age. Shell weight and shell percentage were significantly different at both ages (lower for conventional 6 birds/cage), and both parameters declined with age.

There was no significant difference between systems of housing for albumen hight and Haugh units measured at either 35 or 70 weeks of age. However, there was a significant ($P<0.05$) lowering of the albumen height and Haugh units irrespective of the housing system as the birds aged. Yolk colour measured at both 35 weeks of age were significantly (P<0.0001) different between systems, being deeper in birds in free range, but at 70 weeks of age no differences between systems were found. There were differences between different sampling points showing that at the end of lay hens produce yolk with a deepened colour.

3.3 Mortality

Average mortality was significantly ($P<0.05$) affected by housing system (Figure 18). The highest mortality rate was measured in barn reaching at approximately 34% by the end of lay. In other systems mortality was lower (12-18%), though higher than expected. The barn flocks experienced severe cannibalism and required beak trimming during lay. Figure 19 demonstrates that mortality was rapidly increasing during each three 15 days period preceding beak trimming. After birds beak trimming, cannibalism stopped and the mortality dropped significantly.

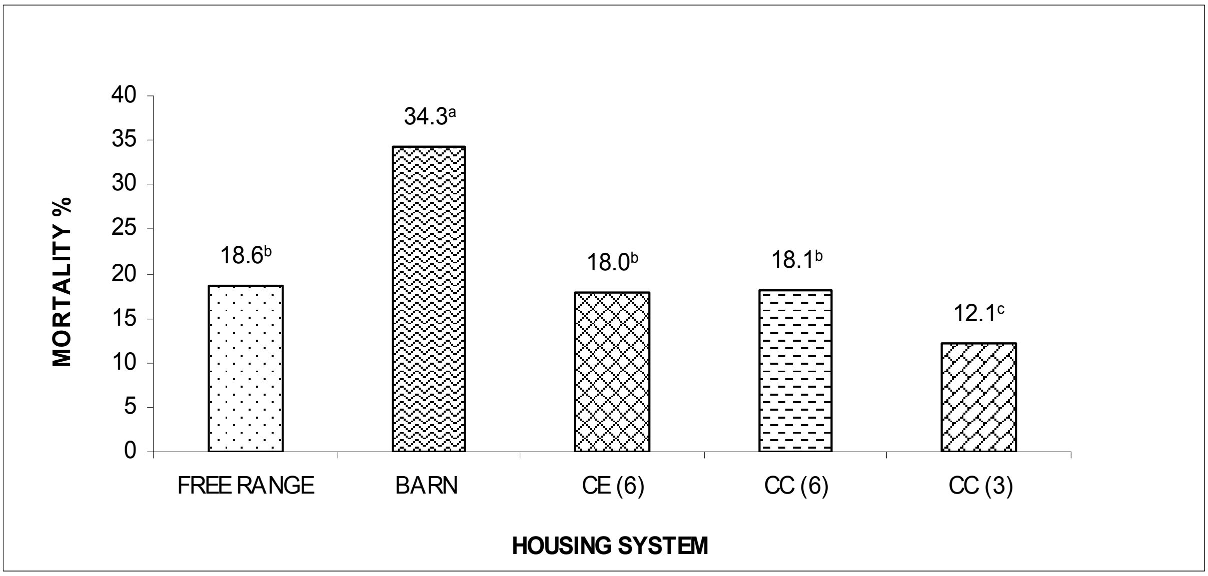


Figure 18. Average mortality and culls for all systems.
Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at $P<0.05$

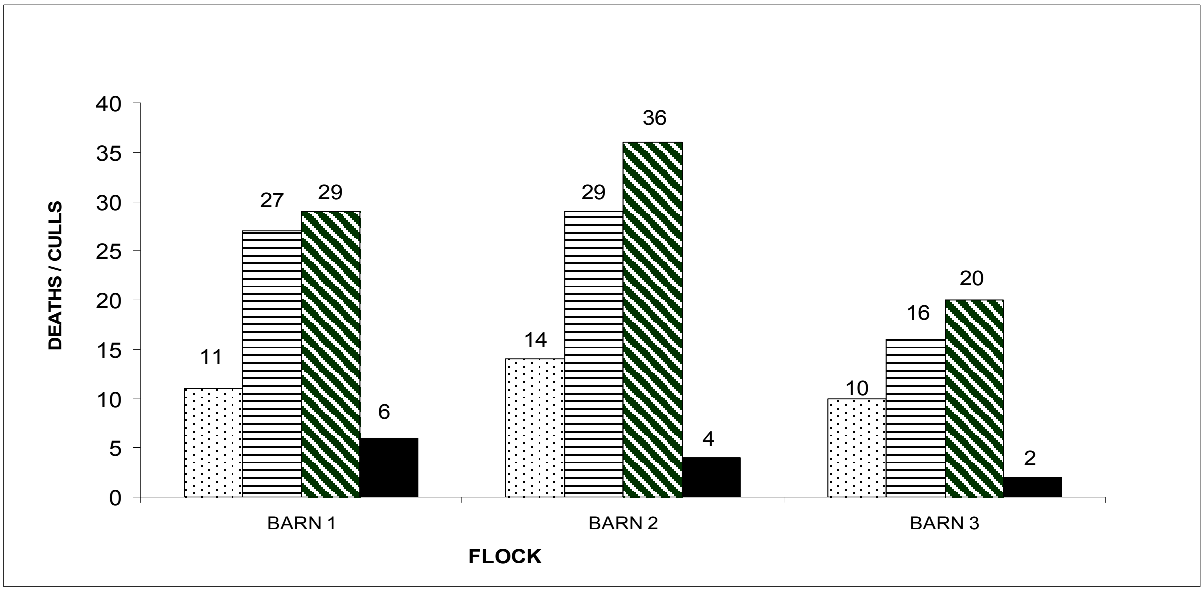


Figure 19. Mortality and culls for 3 barn flocks over 4 x 15 day periods including one period after beak trimming.
Data are presented for each 15 days period. Beak trimming was conducted on 13th of October 2003 (end of third period).

3.4 Feed consumption and feed conversion ratio

Average daily feed consumption is presented in Figure 20. There were significant differences in feed consumption between birds in different housing systems, with hens in barn having the lowest feed intake and hens in 3 bird cages consuming the more feed ($P<0.05$).

Beak trimming significantly effected feed consumption of barn hens. Feed consumption was already falling (Figure 21) due to the cannibalism prior to beak trimming, but rose after trimming.

Average FCR is presented in Figure 22 and demonstrates that birds in all other systems utilise feed significantly better than birds in barn. Birds in free range appeared to utilise feed at the same level with controlled environment and conventional cages 6 hens/cage system.

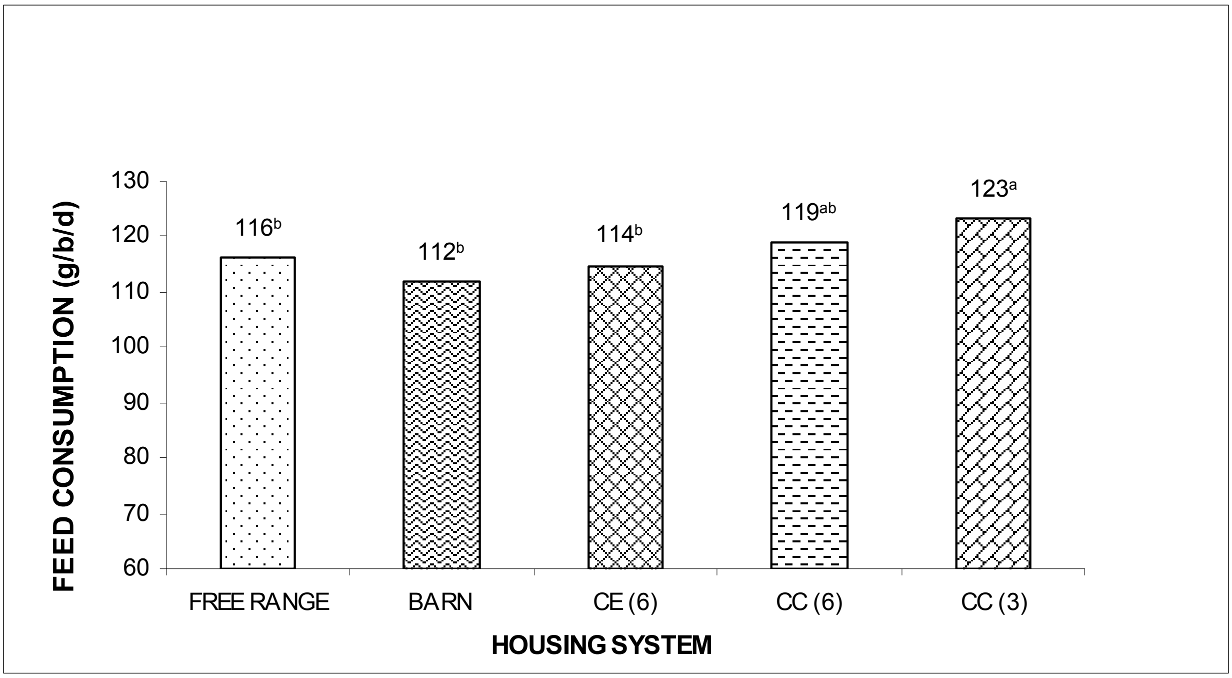


Figure 20. Average daily feed consumption (g/b/d) in all systems.
Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at $P<0.05$

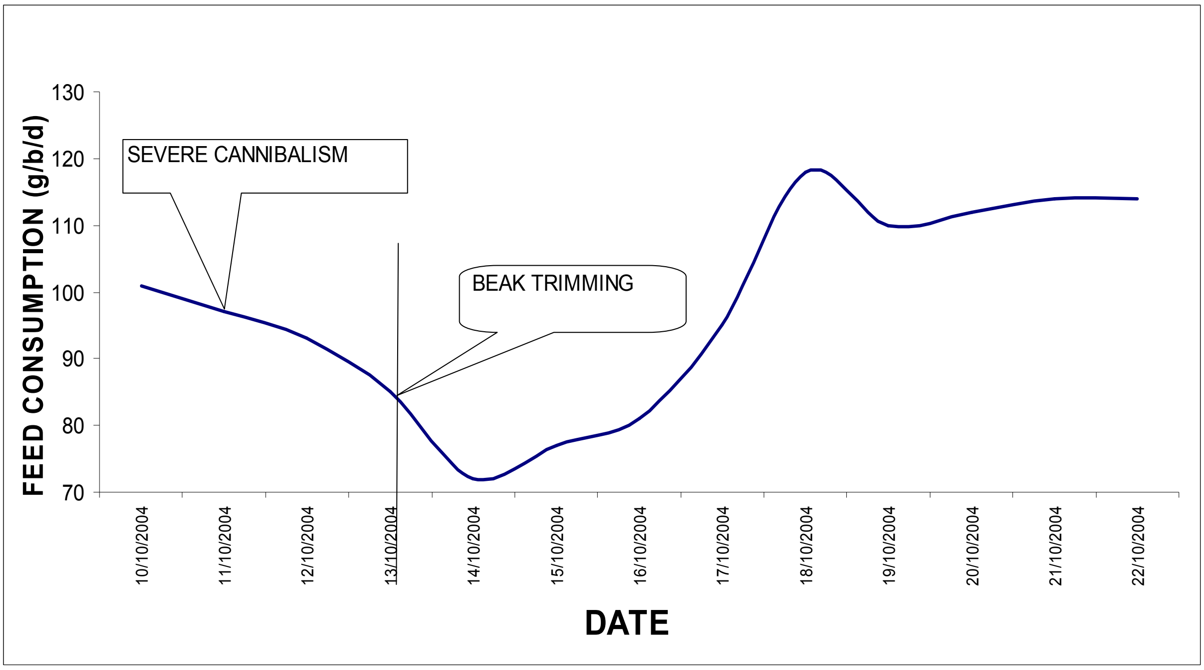


Figure 21. The effect of beak trimming on feed consumption of barn flocks.

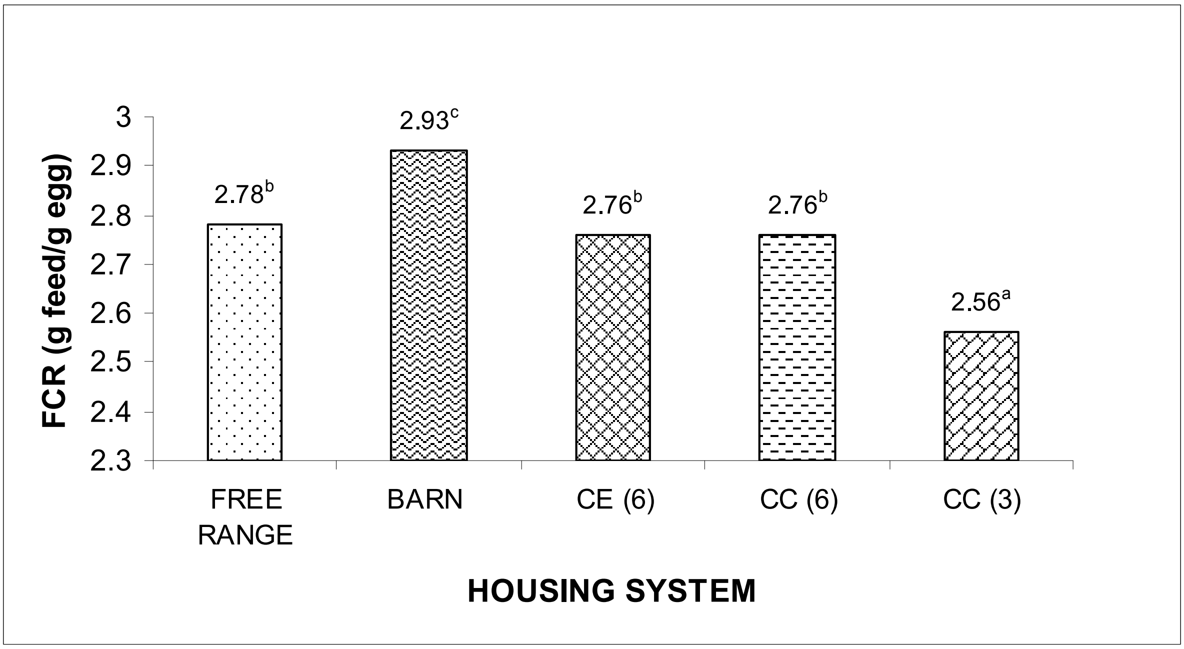


Figure 22. Average feed conversion ratio for all systems.

Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at $P<0.05$

3.5 Body weight

At the beginning and end of lay there were significant (P<0.05) differences in body weight of hens (Figure 23) in the different housing systems. In contrast to other groups, birds in free range weighed significantly less at the end of lay than at the beginning. Free range hens also had the lowest final weight. The change in body weight (Figure 24), between the start of lay (19 weeks of age) and end of lay (70 weeks of age) demonstrated the effect of housing in layers. This was most obvious in layers caged in the controlled environment system. These birds had a 17.6% increase in body weight during lay.

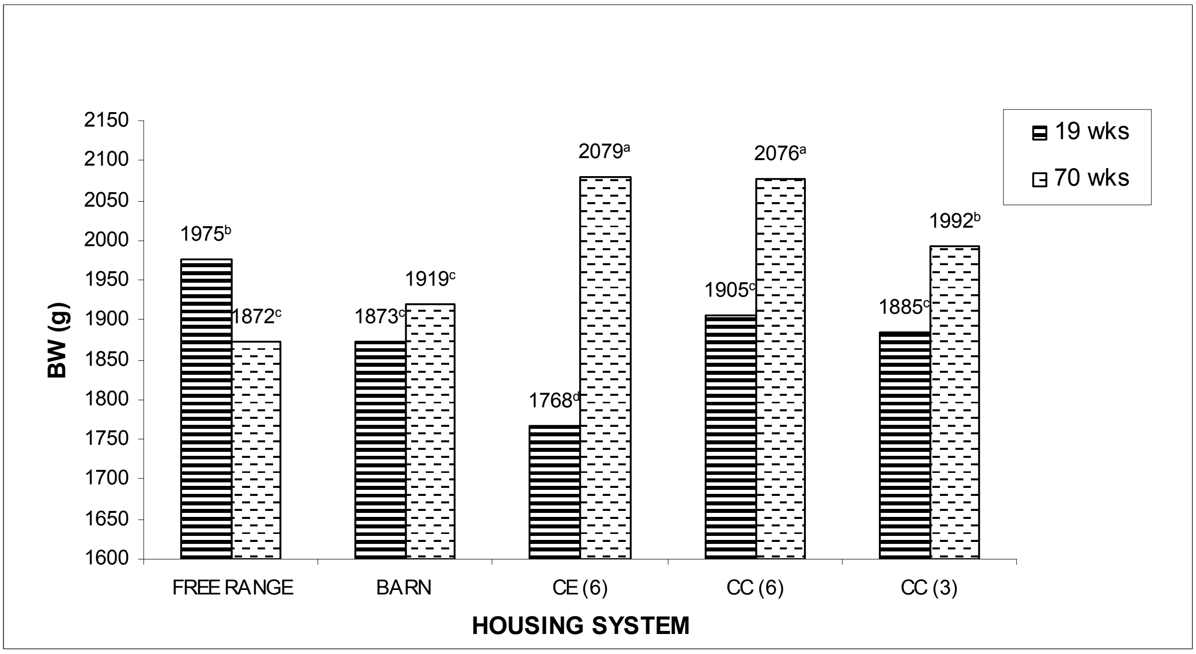


Figure 23. Average body weight of hens at start (19 weeks of age) and end of lay (70 weeks of age) for all systems.

Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at P<0.05

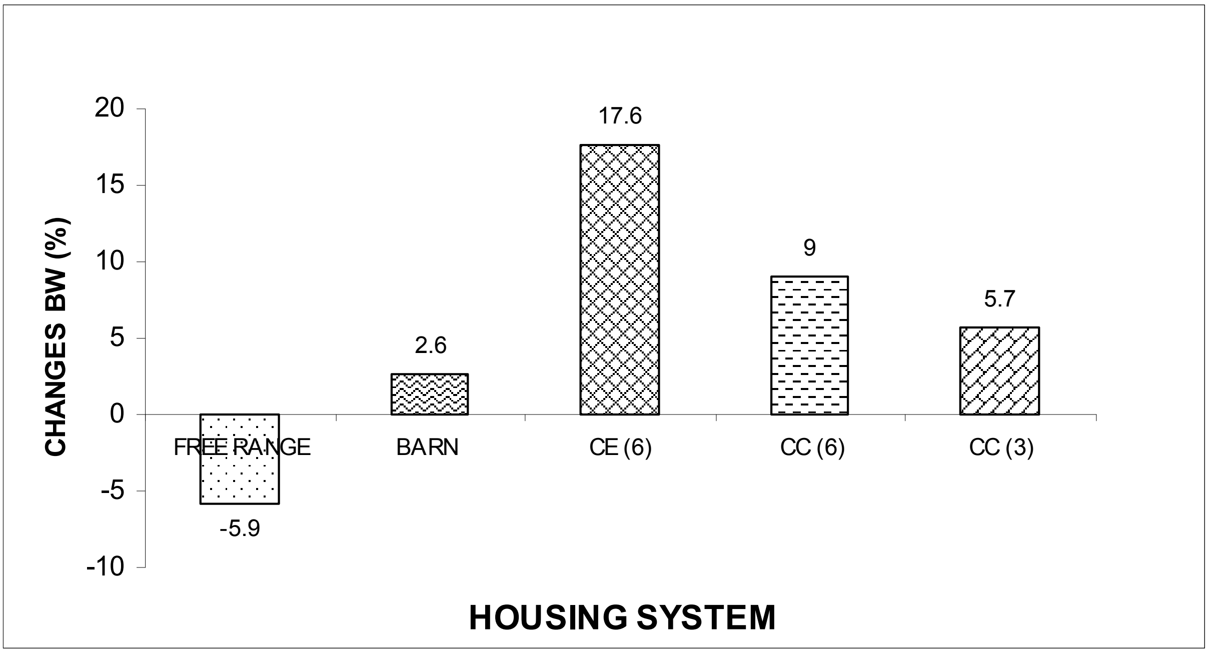


Figure 24. **Changes in body weight (%) between 19 and 70 weeks of age for all systems.**
Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at *P*<0.05

3.6 Physiological parameters

3.6.1 Egg albumen corticosterone

Data showing the effect of different housing systems on egg albumen corticosterone concentrations at 35 and 70 weeks of age are presented in Figure 25. At 35 weeks of age measurement of corticosterone in egg albumen did not indicate significant differences between housing systems (overall mean 1.55ng/g). At 70 weeks of age birds showed lower concentration of corticosterone in egg albumen (Figure 25) than at 35 weeks of age. It should be noted that at 70 weeks of age hens in barn showed a significantly (P<0.05) higher concentration of corticosterone in total albumen (Figure 26).

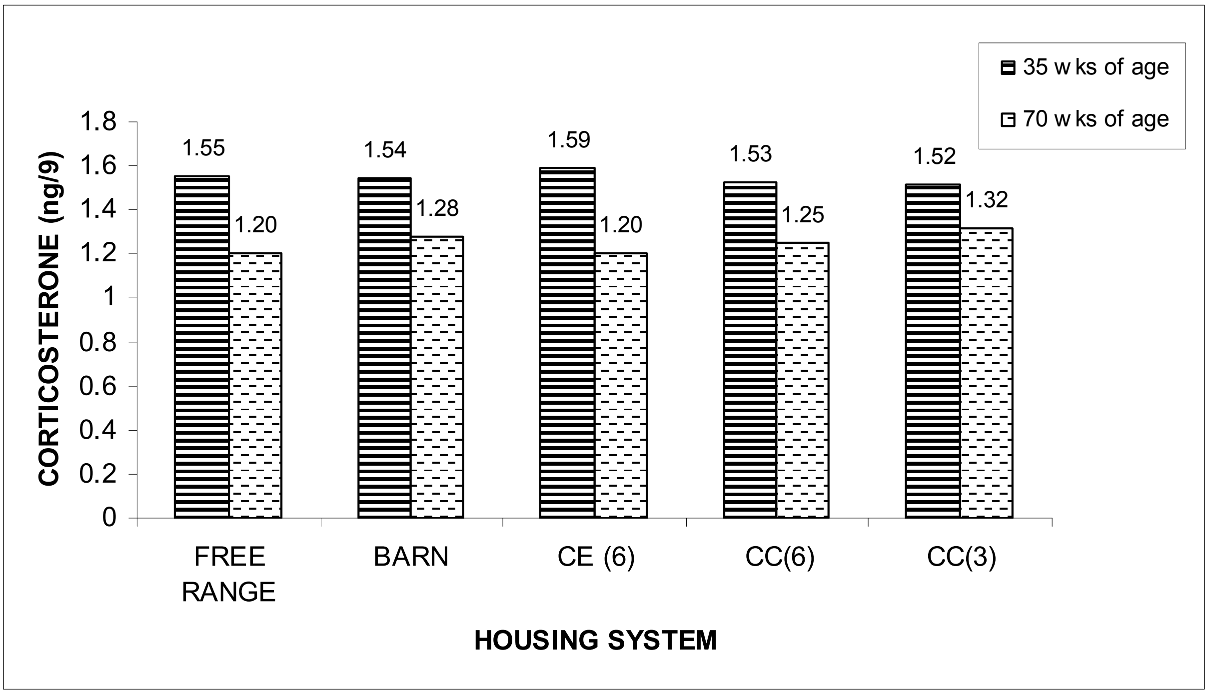
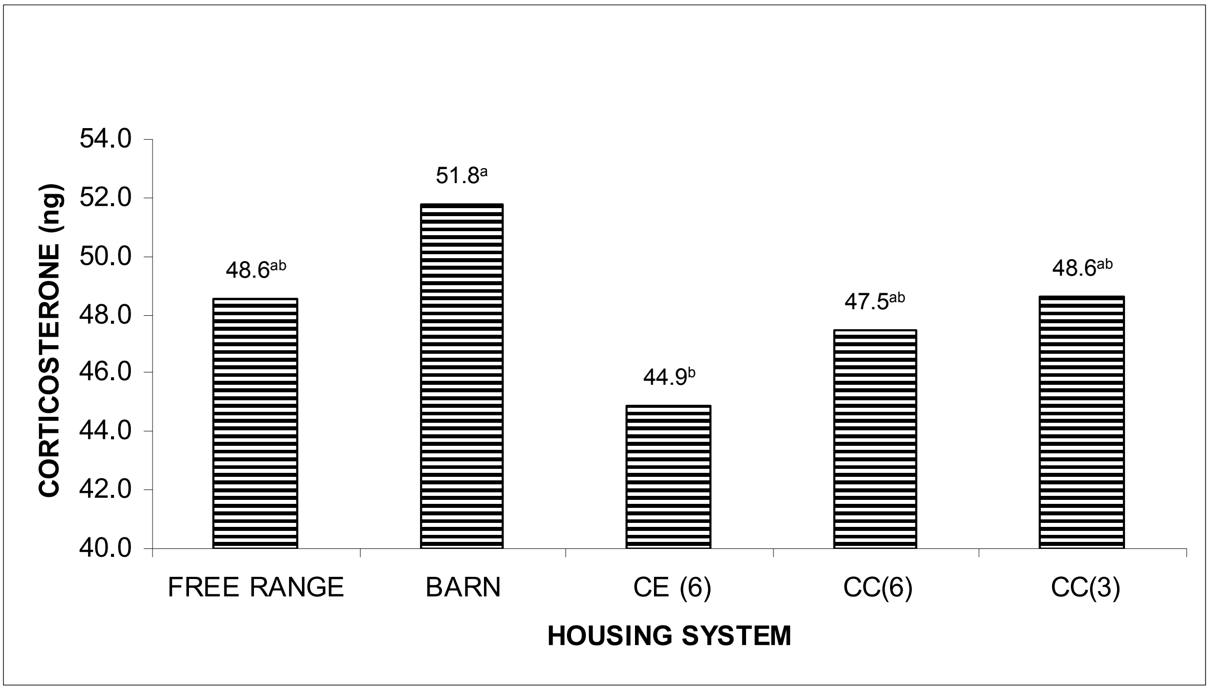


Figure 25. Egg albumen corticosterone concentration at 35 and 70 weeks of age in all systems.

Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at P<0.05



.Figure 26. Total egg albumen corticosterone concentrations at 70 weeks of age.
Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at $P<0.05$

3.6.2 Blood leukocyte profile

The results for differential leukocyte count and H/L ratio are presented in Table 2 and Figure 27.

Table 2. Leukocyte profile at 33 and 63 weeks of age in different housing systems

Cell (% of total)	Housing system				
	FREE RANGE	BARN	CE(6)	CC(6)	CC(3)
33 weeks of age					
Heterophil	17.2	30.5	26.3	25.9	24.5
Lymphocyte	72.1	58.3	65.1	65.7	69.2
Monocyte	5.97	5.70	5.31	4.78	4.33
Eosinophil	2.97	3.03	1.94	1.86	1.13
Basophil	1.77	2.50	1.34	1.64	0.87
63 weeks of age					
Heterophil	23.6	27.4	29.2	27.3	28.9
Lymphocyte	68.4	64.9	63.8	65.4	63.5
Monocyte	4.27	4.33	4.14	4.50	4.07
Eosinophil	1.53	1.46	1.33	1.36	1.93
Basophil	2.13	1.90	1.53	1.42	1.67

Abbreviations: CE (6) – controlled environment (6 hens /cage); CC (6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at $P<0.05$

The differential leukocyte count showed that at 33 and 63 weeks of age percentage heterophils were increased and percentage lymphocytes were decreased in barn hens; accordingly, higher ($P<0.001$) H/L ratios were found in barn hens, as compared with other systems. Data correlated with mortality rate and total albumen corticosterone concentrations (which were also higher in barns (Figure 18 and Figure 25). At 33 weeks of age the lowest H/L ratio was found in hens in free range ($P<0.05$), whereas in all cages H/L ratio ranged from 0.35 to 0.40. However, at 63 weeks of age, hens in barn indicated a lower level of H/L ratio than at 33 weeks of age; hens in *Euro-vent* and double cages maintained the same level of leukocyte cells and H/L ratio at both measurements (33 and 63 weeks of age); hens in free range demonstrated an increase ($P<0.05$) in heterophils and H/L ratios as compared with 33 weeks of age. For different reasons hens in conventional 3hen/cages have increased H/L ratio at 63 weeks of age which correlates with a higher level of egg production and total albumen corticosterone concentrations in these hens (Figure 14 and 25).

Results for other circulating blood cells, reported in Table 2 show that there were slight differences between housing systems. Again, at 33 weeks of age hens in the barn system demonstrated the highest values in eosinophils and monocytes, indicating that the nonspecific immune response was altered, and at 63 weeks of age hens in free range showed the highest level of basophils.

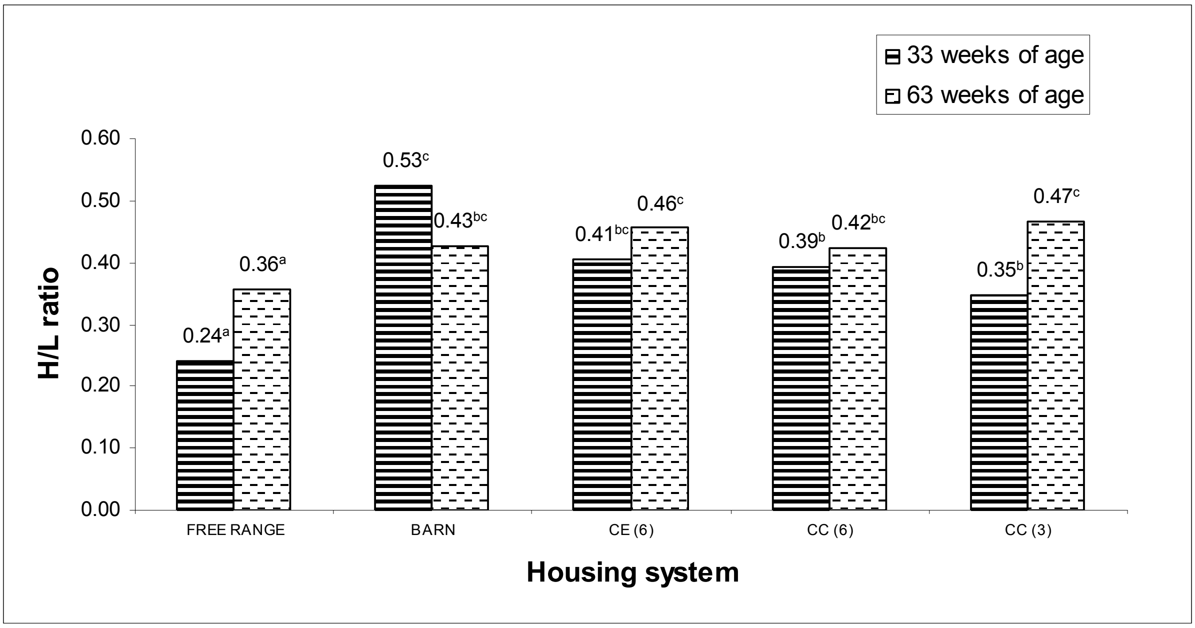


Figure 27. **H/L ratio at 33 and 63 weeks of age for hens in all systems.**
Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at $P<0.05$

3.6.3 Bone strength

Bone strength data are summarised in Table 3. The strength of femur and humerus bones from birds in cages was significantly (P<0.001) lower than in alternative systems. When compared with the humerus bone, the femur bone demonstrates a higher strength for hens in all systems.

Table 3. Breaking strength (kg) for humerus and femur bones in laying hens at the end of lay (70 weeks of age)

Housing System	Humerus	Femur
FREE RANGE	$35.52^{a}\pm1.33$	$43.16^{a}\pm1.14$
BARN	$38.59^{a}\pm1.31$	$41.23^{ab}\pm1.24$
CE (6)	$24.10^{b}\pm0.86$	$37.83^{bc}\pm1.84$
CC (6)	$26.49^{b}\pm1.09$	$35.10^{c}\pm1.93$
CC (3)	$25.32^{b}\pm1.14$	$36.34^{c}\pm1.85$

Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage). Columns with different letters are significantly different at P<0.05
Significant difference for humerus breaking strength (P<0.0001)
Significant difference for femur breaking strength (P=0.0008)

3.7 Behavioural observations

3.7.1 Movement

At the end-of-lay, hens in conventional 3 hens/cages moved significantly less ($P<0.005$) between the front and back of their cage than hens in conventional 6 hens/cage and controlled environment cages (Figure 28). Hens were more often at the front of the cage than away from the front. The use of the front of the cage differed significantly ($P<0.05$) between cages. Hens in conventional 3 hens/cage system did use the front of the cage less than hens in conventional 6 hens/cage and controlled environment cages. The proportion of hens with heads out at any one time was significantly ($P<0.001$) different in different cage types with a lower proportion of hens with heads out in controlled environment cages. Within systems, the number of hens in the cage did not significantly affect the proportion of hens with heads out.

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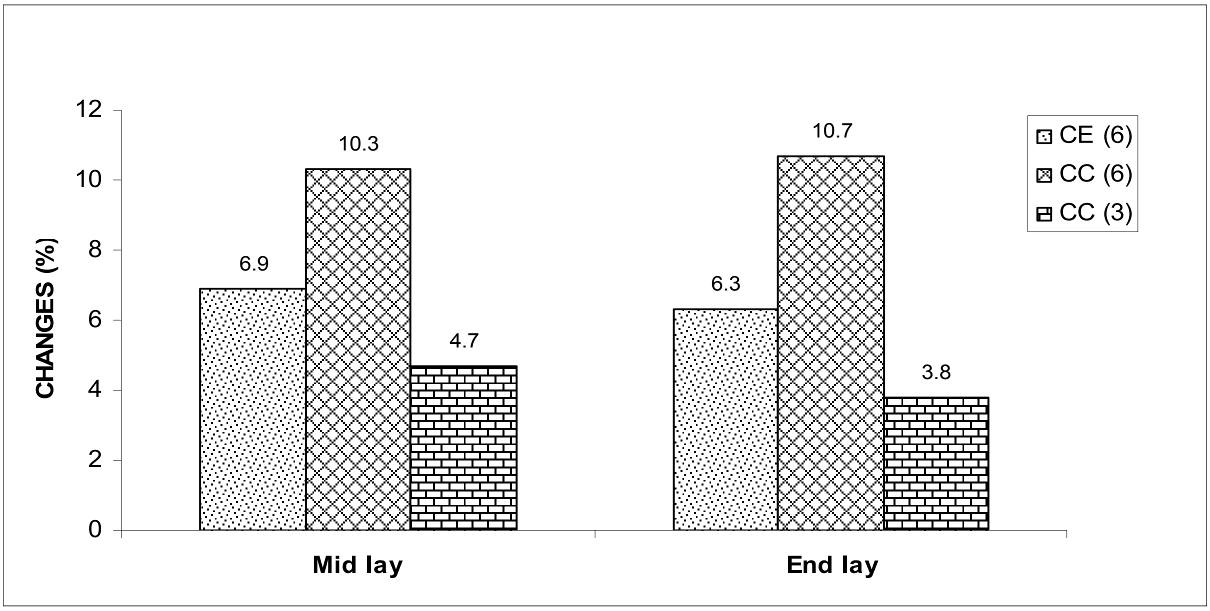

Figure 28. **Movement of hens between the front and back of the cage at mid- and end of-lay.**

Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage)

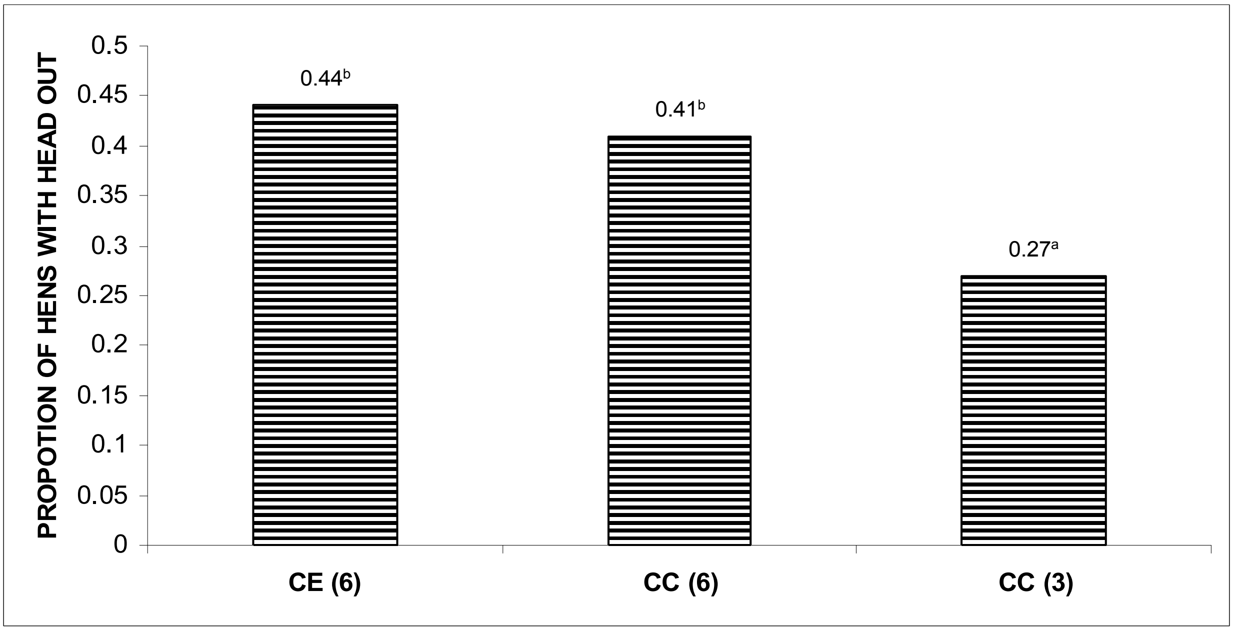

Figure 29. **Mean proportion of hens in cages with heads out either feeding or looking at any one time.**

Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage

Columns with different letters are significantly different (*P*<0.05).

Data show that the number of steps for hens housed in conventional cages at end-of-lay was significantly lower (*P*<0.005) than for those in the controlled environment cages. However, space per hen varied during the study as a result of mortality.

In barn system, the mean times a hen moved between the floor and the slat area during a five minute observation period was 0.52 at mid-lay i.e., the hens moved between being on the floor and the slat area on average every 9.6 minutes. At end-of-lay, they moved between slats and floor every 6.7 minutes, but the difference was not significant (*P*<0.1465). In free range, hens on average moved between being inside and outside every 13.5 minutes. At end-of-lay that time period had increased to 25 minutes. This difference was also not significant (*P*<0.0989). Hens in barn moved freely between the floor and the slats, and hens crossed readily from one side of the barn to the other around either end of the nest row. Percent of scaned hens in free range that were inside and outside was about equal at mid-lay, while hens spent less time outside at end-of-lay.

Hens perched for only a small proportion of the time during the day in both barns and ranges. The distribution of hens at night in barn and range was measured during one night at end-of-lay. At night, most range hens were perching (the majority on the perches, but some on the metal bars over the feeders). In barns, the metal bars were favoured by the hens at night, with the whole space taken up. Other barn hens were distributed between the slats, floor, in the rafters, on the nests, and in the nests.

Step rate differed between systems at end-of-lay (*P*<0.001) with hens in free range and barn systems stepping significantly more frequently than hens in cages (Figure 30).

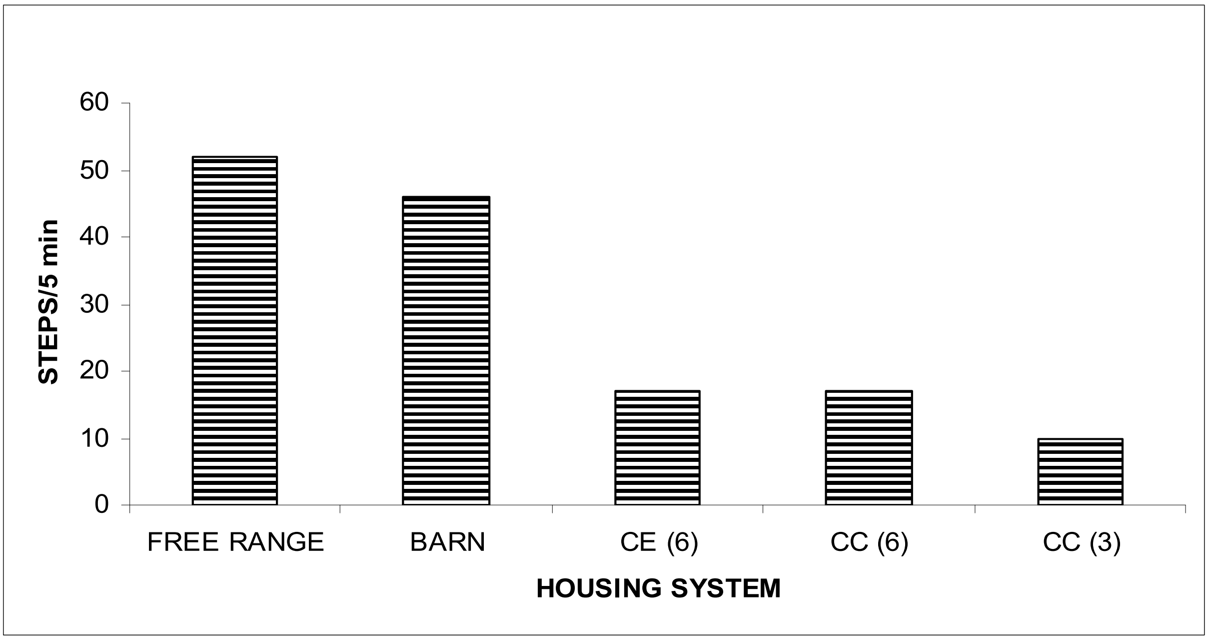

Figure 30. **Mean step rate for each 5 min in all systems at end-of-lay.**
Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage

3.7.2 Other behavioural observations

Behaviour rates of hens in different housing systems are presented in the Table 4.

There were statistically significant behavioural differences between the systems in most activities assessed. Free range hens were much more active that other hens, but interestingly there was very little difference observed between barn and caged hens. Similar observations were made both at mid-lay and the end of lay (Tables 4 and 5). Hens in all systems drank, preened and sat at about the same rates (Table 6).

Aggression did not differ between systems at mid-lay or at end-of-lay, but hens in barns and free ranges were significantly more aggressive at end-of-lay than at mid-lay (data not showed here).

Table 4. Behaviour rates of hens in different housing systems at mid-lay*

Housing system	Feeding	Standing	Standing with head out	Ground pecking	Scratching	Walking	Drinking
FREE RANGE	11^{b}	28^{c}	-	26.8^{b}	4.9	23.5^{c}	4.5
BARN	31^{a}	39^{b}	-	7.6^{a}	0.7	14.2^{b}	2.7
CE (6)	29^{a}	51^{a}	9^{c}	2.8^{a}	0.0	1.3^{a}	5.8
CC (6)	28^{a}	49^{ab}	16^{b}	7.3^{a}	0.0	2.6^{a}	7.1
CC (3)	32^{a}	53^{a}	25^{b}	4.7^{a}	0.0	0.8^{a}	5.5
SEM	4.0	3.5	1.6	2.5	1.33	0.65	1.4
P	<0.0222	<0.0025	0.0013	0.0003	0.1046	0.0001	0.3052

Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage
Columns with different letters are significantly different ($P<0.05$).
* Ground pecking includes grass pecking in range. Scratch is ground scratching.

Table 5. Behaviour rates of hens in different housing systems at end-of-lay.

Housing system	Feeding	Standing	Standing with head out	Ground pecking	Scratching	Walking	Drinking
FREE RANGE	14	31^{c}	-	18.9^{b}	0.9^{b}	15.8^{b}	5.6
BARN	15	37^{bc}	-	19.6^{b}	0.6^{a}	17.4^{b}	4.1
CE (6)	26	50^{a}	6.2^{b}	2.2^{a}	0.6^{a}	3.1^{a}	5.8
CC (6)	27	44^{ab}	21^{a}	3.6^{a}	0.0	3.3^{a}	7.2
CC (3)	20	51^{a}	22^{a}	3.3^{a}	0.0	0.7^{a}	7.0
SEM	3.3	3.3	0.7	2.49	0.11	1.2	1.5
P	<0.0659	<0.0071	0.0409	0.0006	0.0002	0.0001	0.6088

Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage
Columns with different letters are significantly different ($P<0.05$).
* Ground pecking includes grass pecking in range. Scratch is ground scratching.

Table 6. Preening and sitting of hens in different housing systems (mean percent of scanned hens preening and sitting at mid-lay and end-of-lay).

Housing System	Preening* Mid-lay	End-of-lay	Sitting** Mid-lay	End-of-lay
FREE RANGE	2.7	4.6	3.9	10.6
BARN	1.9	2.9	4.1	2.9
CE (6)	4.2	9.0	6.9	5.3
CC (6)	2.1	7.2	3.3	7.8
CC (3)	2.4	8.3	2.7	10.8
SEM	1.35	1.57	1.67	2.66
P	0.6667	0.0914	0.4824	0.2389

Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage

Columns with different letters are significantly different (P<0.05).

*Preening includes sitting and preening. **Sitting includes sitting and preening.

3.8 Feather and foot condition

3.8.1 Feather pecking and feather condition

Feather pecking by hens in different systems was significantly different (P<0.0198 and P <0.0074 at mid- and end-of-lay, respectively). At mid-lay hens in barns feather pecked significantly less than hens in cages, while hens in free range pecked significantly less than hens in conventional and double cages. At end-of-lay, barn and free range hens feather pecked significantly less than caged hens. Feather pecking rates did not change significantly between mid- and end-of-lay. Dust-bathing hens were often feather pecked by other hens not dust-bathing. A total of 35 dust-bathing hens in each of barn and range were each observed for five minutes and the number of hens that pecked them, and the number of bouts of pecking was recorded. There was a trend for hens dust-bathing in the free range to be more often feather pecked than hens in barns.

Data, showing the percent of hens with extensive damage to the abdomen, neck and wing showed that scores of free range and barn hens were better for neck and wing than for abdomen scores, which were less that for hens in cages. The neck and back scores of hens in controlled environment cages were intermediate between the other cage systems and the alternative housing systems. The total scores of separate body parts of hens in cages were similar irrespective of cage type.

Mean total of feather scores did not differ between systems (P<0.8510), (Table 7). However, feathering of different body parts was significantly different between hens from different systems.

Table 7. **Feather damage (mean of percentage feather scores of separate body parts of hens in each system).**

Housing system	Neck	Wing	Back	Side	Tail	Abdomen
FREE RANGE	53.3^{c}	91.4^{b}	42.1^{a}	57.2^{a}	53.6	43.1^{b}
BARN	38.2^{b}	54.3^{a}	45.8^{a}	62.5^{ab}	49.8	64.9^{bc}
CE (6)	86.2^{d}	99.2^{b}	45.2^{a}	54.8^{a}	39.7	12.0^{a}
CC (6)	27.5^{a}	61.6^{a}	56.1^{b}	70.3^{b}	56.1	73.2^{c}
CC (3)	27.8^{a}	45.3^{a}	62.5^{b}	60.9^{a}	50.2	86.3^{c}
P	<0.0001	<0.0001	0.0066	0.0413	0.0660	0.0006

Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage
Columns with different letters are significantly different (*P*<0.05).

3.8.2 Foot condition

Apart from claw overgrowth in barns and cages, all feet examined were in reasonable condition, with no extensive injures nor development of bumble foot. However, most of the feet of caged hens showed calluses, with nearly all hens in conventional cages, and half the hens in *Euro-vent* cages. The degree of foot damage did not differ between cage types (Table 9). The claws of hens in the ranges were mostly well worn down and the amount of wear was fairly uniform. The claws of free range hens were significantly shorter than claws of hens from all other systems. The underside of the feet of free range hens were dirty, but the feet appeared to be in good condition.

Table 8. Foot condition of hens in each system at end-of-lay

Housing system	Mean Claw length (mm)	Maximum length (mm)	Minimum length (mm)	Proportion damaged	Mean degree of damage
FREE RANGE	13.1^{a}	16	12	0.03	0.03^{a}
BARN	21.1^{b}	30	14	0.03	0.03^{a}
CE (6)	23.2^{bc}	37	14	0.6	0.75^{b}
CC (6)	23.6^{c}	30	20	0.7	0.90^{b}
CC (3)	24.7^{c}	29	22	0.9	1.06^{b}
P	<0.001				P<0.001

Abbreviations: CE (6) – controlled environment (6 hens /cage); CC(6) – conventional cages (6 hens/cage); CC(3) - conventional cages (3 hens/cage
Columns with different letters are significantly different (*P*<0.05).

The feet from the barn hens were clean, in good condition, and their claws had blunt tips and were significantly longer than those of hens in ranges (P<0.0001). However, the claws were significantly shorter than claws of hens in cages (P<0.0023). Claws of caged hens were generally sharp, and claw length did not differ significantly between hens from the three cage types. As demonstrated by the maximum and minimum lengths, the lengths of the claws were the most uniform in free range hens (Table 9). The feet from hens in cages were generally moderately callused but more so than birds on free range or barns.

4. Discussion

Following international developments and public debate in Australia there have been concerns about the impact that restricted and barren environment of conventional cages have on some aspects of the welfare of laying hens. Scientific data were needed to assess the quality of hens and their production in different housing systems. It must be noted that all systems used in this study have their strengths and weaknesses with respect to health and welfare of hens, food safety, and requirements for labour and husbandry skills, occupational health and safety for operators and environmental protection.
Studies overseas in this field have shown difficulty in interpreting data because of insufficient replicates and variation of the results. The research conducted in this trial was unique regarding the degree of standardisation which has been achieved (strain, month of placement, diet, climate, management practices, vaccinations and quantitative measurements). It was required that as many physical and physiological parameters as possible to be assessed for each laying system including, hen health and welfare, production, egg and bone qualities.

The effects of conventional and alternative housing systems on the production, physiology and behaviour of laying hens were examined to explore the relationship between the housing systems and the biological responses of hens during the laying cycle. As emphasised at the beginning of this report, an evaluation of different housing systems using multiple criteria was required for a better understanding of bird production performance and an accurate assessment of its health and welfare. This study was the first one that has used enough replicates and many physical and physiological parameters to analyse the overall production, behavioural and physiological response of laying hens in conventional and alternative housing systems. From 19 to 70 weeks of age laying hens were housed and assessed in five different housing systems with three replicates of each housing type. The diet and management were comparable for all different housing systems taken under assessment.

The results of this investigation showed that housing system influenced in various ways the production performance, endocrine and immune responses, and health and behaviour of laying hens during lay cycle. From the parameters measured here there were significant differences in production, mortality, behaviour and physiology of hens. However, in interpreting of the data of this investigation it should be noted that there were some implications during the assessment that may have influenced results. Of importance were some drops in production due to: symptoms of EDS (in all flocks at peak of lay, 33-35 weeks of age), an acute outbreak of cannibalism in the barn flocks at approximately 47 weeks of age, and a significant heat wave at around 61 weeks of age.

As described in the results there were significant differences in HHP between different housing systems. Hens seemed to produce comparably, though hens housed in conventional cages 3 hens/cage achieved the highest production rate (76%). For all systems HHP over the 52 week lay cycle showed that after reaching peak, production decreased over time. Because egg producers commonly compare the performance of their flocks by comparing the number of eggs per hen housed, this parameter was also measured. It was confirmed that hens in conventional cages (3 hens/cage) produced more than hens in barn, free range, conventional cages 6 hens/cage, and controlled environment cages. The conventional cages 3 hen/cage system had also the highest egg weight, and the lowest mortality (ca. 12%). On the other hand, hens housed in barn demonstrated the lowest level of production (ca. 60%) and the highest mortality (ca. 34%). The level of broken eggs was high in barn system, which indicated that the effectiveness of the hens to produce eggs of good shell quality and of the laying facilities to protect those eggs from damage after lay was insufficient. Moreover, the results of egg breakage demonstrated that, the number of broken eggs was affected by housing (stocking density) and the state and management of the facilities – e.g. slope of floor, the number of eggs in the roll-out, time of pick-up, number of collections etc. In most of all egg quality parameters did differ slightly between systems, though anecdotal evidence suggests that of marketing significance for range producers is that range egg buyers generally prefer/expect a rich brown coloured egg shell and a deep yolk colour. It was expected that free range hens (with access to green pasture) produce the highest yolk colour readings. As results showed, irrespective of the housing system, yolk colour was deeper as the hens aged. This might have been just a result of increasing intake of pigment as the birds consume more feed as they age combined with lower production of eggs at the end of lay. As regard to feed consumption and FCR, it was indicated that hens in controlled environment cages and hens in conventional cages 3 hens/cage consume more feed per day than hens in barn, conventional cages 6 hens/cage and free range. Presumably, the way that hens were fed affected the amount of feed they consumed/wasted. Hens in free range and barn were fed from automatic chain feeders (operating 6 times per day); hens in cages were all fed manually: conventional cages, (6 hens/cage) and (3 hens/cage) had old type wide troughs which were normally fed up every second day – however, grids were placed within the troughs to reduce feed wastage; hens in controlled environment cages were fed manually daily, though cages were fitted with a narrow automatic chain fed trough. The results of feed consumption showed that the more productive hens the more feed used (as was the case of hens in conventional cages 3 hens/cage); and of course, the more active hens (e.g. hens in free range and barn), the higher (the worse) the feed conversion ratio. Hens in controlled environment cages demonstrated high feed intake and moderate FCR, even though a larger part of feed may have been used to put on the weigh (as showed from the results of body weight). It was to be thought that the relatively high increase in body weight for hens in controlled environment indicated that the nutrient density of the ration (which was formulated for an intake of 110 g/bird/day) may need to be consider/decreased in order to reduce body fat deposition. However, it was seen that body weight generally increased quickly after being caged and then flattened out as the birds aged.

Albumen corticosterone concentrations indicated that the drop in corticosterone concentrations at 70 weeks of age compared with that at 35 weeks of age in all flocks suggested that birds adapt better (or are less stressed by their macro and micro environment) as they get older, whatever the housing system was. This did not happen with H/L ratio which also was used as an indicator of stress. Total and differential white blood cell counts were altered differently at different measurements (33 and 63 weeks of age), suggesting alteration of the cell response due to stress and/or bacterial infection. As known white blood cells may be affected by a variety of factors/stressors which consistently elevate the heterophil/lymphocyte ratio (Gross and Siegel, 1981, 1983), although other external and internal invaders may affect these cells as well. At 33 weeks of age H/L ratios of birds housed in the barn system showed that they had been exposed to some degree of stress. Clearly, factors such as large flocks, overcrowding and a barren environment in the barn system presumably induced stress (around 33-35 weeks of age) that subsequently were manifested by an aggressive behaviour (cannibalism outbreak at about 40 weeks of age) in hens. Furthermore, on the end of lay hens in barn hens showed a significant increase in total albumen corticosterone concentrations (51.8ng) and mortality (ca. 34%), but not H/L ratio (0.43). The presence of microbial agents in alternative housing conditions such as barn system might have been the reason why heterophils were increased at the start of lay. After birds have acquired their immunity against bacteria the number of hetrophil cells was stabilised. A sufficient number of circulating leukocytes in appropriate proportion is essential for hens to produce an immune response against. However, an increase in H/L ratio does not always indicate the presence of stress, though microbial agents are considered to be stress factors per se. Other leukocyte counts were moderately changed. Basophils and eosinophils were also increased in barn hens. As nonlymphoid immune cells with phagocytic activity, these leukocytes demonstrate an alteration of nonspecific defence mechanisms to potential microbial contaminants of the barn system. It was assumed that factors influencing the mortality in the barn system were persistent over time, therefore affecting the physiological-immunological response of birds, followed by the alteration of the response of these biological systems.

As expected exercise was highly correlated to bone strength and consequently, free range and barn birds have had stronger femurs than similar birds housed in cages. Those housing systems which allowed for unimpeded ability for the birds to flap and stretch their wings and to use their wings for jumping/flying without impedance resulted in the strongest humeri.

Behaviour results showed that most of behaviours were similar at mid- and end-of-lay. The larger conventional cages (double, 6 hens/cage) and controlled environment (*Euro-vent* type) cages gave

more freedom of movement to the hens than the smaller conventional cages (3 hens/cage). However, hens in small conventional cages did not appear to be restricted in their use of different parts of the cage as compared to the hens in the larger cages. Hens in the barn and free range systems used their extra space to walk about more than hens in cages, they were able to move freely about their enclosures, and were about equally distributed between floor and slats in barns, and inside and outside the shed in free range. Hens in free range fully used their perch space at night, and few non-laying hens occupied the nests. Hens in both barn and free range occupied perches less than 10 percent of the time during the day. Barn hens preferred to perch on the metal bars over their food rather than the slats at night, with those that did not fit on the perches distributing themselves about the enclosure, including nests. The behaviour rates of feeding, standing, ground pecking, scratching, walking, and feather pecking indicated that the extra stimuli provided by barn and free range systems were at least partially successful in directing behaviours away from non-feeding pecks at food and feather pecking. The incidence of feather pecking was reduced on alternative housings compared to cages indicates that the extra stimuli were able to redirect some pecks away from flockmates' feathers. This was in accordance with many studies that have shown a greater incidence of feather pecking by hens in cages than on alternative housings (Appleby et al, 1992). In spite of the reduction in feather peck rates in barn and free range systems, overall feather scores of hens did not differ between systems. Some unexpected changes were seen in behaviour rates in barn and free range hens over the laying period. Barn hens fed significantly less and ground pecked and scratched significantly more at end-of-lay than they did at mid-lay, while free range hens ground pecked significantly less, walked significantly less, were found on the range less and passed between the shed and the range less at end-of-lay than at mid-lay. Therefore, changes between mid-lay and end-of-lay appeared to be affecting these behaviours. In barns, the litter had been greatly added to by dried faeces, making the particles in it appear more variable than they had at mid-lay. It may have been this greater variability that was encouraging the ground pecking in barns. In ranges, on the other hand, by end-of-lay, most of the grass had disappeared from the ranges (entirely in range 3), and the summer was with long, hot, mostly sunny days. These factors may have been discouraging use of the range by the free range hens.
Food and water were readily accessed in all cage types with feeding and drinking rates at similar levels; they were also accessed freely in the barn and free range systems. The hens fed as often in the barns as in the cages, so they can be regarded as having had free access to the food. Although hens in the free ranges fed less, there was always plenty of space at the feeders, and hens did not appear to have difficulty reaching the food. Drinking rates in all housing systems were about the same, so it appears that hens were able to access water freely in all systems. As regard to feather scoring hens in cages tended to have similar amount of damage over the whole of each body part, while hens on alternative housing tended to have some areas of each body part completely bare, while other parts were well feathered. The time that free range hens spent outside did not seem to affect feather pecking. Judging by foot condition, alternative housing and all cage types were reasonably comfortable for the hens. All feet examined were only mildly calloused, with no extensive damage. In particular, the feet of hens housed in controlled environment cages were less callused, but claws on the outer toes were sometimes broken. These hens were observed often leaning this toe against the edge of the cage while feeding. Nearly all hens in the conventional cages (3 birds/cage and 6 birds/cage) showed some damage to feet, while only just over half of hens in controlled environment cages had some damage, indicating that the floors of these newer cages may be more comfortable than the older style cages. The claws of all caged hens were sharp which could have been a problem when hens stood on one another. No hens examined had bumble-foot, so the perches were of a suitable design. The free range hens had very well worn claws, perhaps due to the nature of the substrate rather than due to more scratching as their scratch rates did not differ significantly.

In conclusion, parameters of performance, physiology and behaviour were of greater importance in assessing the effect of different housing systems on hen welfare. Different housing systems showed different effects, though within biological, nutritional and environmental limits hens seemed to produce at a comparable level. This implies that the physiological mechanisms that underpinned the neuroendocrine-immune response could be altered to maintain homeostasis. It should be noted that different housing systems offered hens different ability to respond to their environment, so that the most important activity for laying hens, egg production was maintained, while health and welfare might have been compromised. Due to complexity of the interactions bird-environment the question, what can be an acceptable layer housing system cannot be answered by one study only. Developments in the future will allow us to describe in some detail the physiological response of laying hens to different environmental conditions and to explain the interplay between the genome and the environment. In so doing, it should be possible to define the most comfortable environment for the hen with a greater precision and therefore increase the health and welfare of the laying hen.

5. Implications and recommendations

This comparative housing laying trial was only the first in a projected series of consecutive laying flock assessment (each of 52 weeks of lay). Replication of this trial with more flocks from the same and other strains will provide a better understanding of how housing systems is related with production and physiology and welfare of laying hens. Consequently, the results should be viewed as an initial trial with more replicates 'in time' to follow. Research such as this (covering a full 52 week laying cycle with over 6000 layers involved) was very expensive in terms of the provision of state-of-the-art facilities, of labour and data processing, and required a strong commitment from participants, industry and research funding bodies to maintain it.

Some of the implications that may be seen in all systems and general recommendations to prevent them are given bellow:

• Acute outbreak of disease (i.e., Egg Drop Syndrome) because of failure of vaccination. In this study, nevertheless the purchased birds have been vaccinated against EDS that didn't mean 100% protection. For different reason there were an insufficient function of defence mechanisms following with clinical signs of EDS and reduction of production. It is to be recommended that a serological monitoring of the flock prior to point of lay for some of the most prevalent disease (i.e., IBV, NDV, and EDS) might prevent such events.

• Though, barn system provided freedom of movement and the opportunity to dustbathe, problems with cannibalism and bullying were seen often. Outbreak of cannibalism in the barn flocks at 47 weeks of age decided that all the barn birds should be beak trimmed to stop further injury to the birds. This 'mid-lay' beak trimming effected on mortality, hen day production and daily feed consumption. Beak trim of birds destined for barn production at day-old (or under 10 days of age) may serve as a preventative measure in large flocks with more than 4-500 birds housed together.

• High summer temperatures showed a significant effect on production and mortality. Specific recommendations are given bellow.

5.1 Free range housing system

• To increase the shed areas and improve range quality can be ensured by planting trees, or by planting tall shade-providing grasses or shrubs. Suitable shade plants (e.g. silk sorghum) might be incorporated in special pasture mixes with deep rooting characteristics.

• A shade cover verandah is recommended (3m wide outside) and parallel to the northern and southern walls of the shed to help entice hens out of the shed during hot weather, to provide a protected shaded area between the shed and the range, and to cool the shed by shading the main northern wall.

• In periods of extreme heat, water may be supplied in and around the sheds to allow the formation of small rivulets/pools in which birds can wet their faces and wattles.

• Water supply to nipples should not be in direct sunlight or water lines and should not be subject to radiation from shed structures.

• Water lines leading to nipple drinkers may be placed under the litter rather than on top of it.

• An establishment of a rotational grazing system within each main range may be used to see if ground cover may be better maintained throughout lay.

• In range areas that have been made bare, it would be recommended to install hay racks or place bales of hay on the ground to improve behavioural stimuli – particularly foraging behaviour.

5.2 Barn system

• The use of a water misting system (atmosphere washing) is recommended to reduce dust within the shed.

• Alternative litter materials (other than pine shavings) may encourage more ground pecking and scratching, and also lower dust levels.

• Whirly-bird extractor fans may be installed to improve the airflow within the shed.

• Light restricting curtains could be hung outside of the shed and would encompass the shed shutters to reduce light intensity and modify bird behaviour (possibly reduce the incidence of cannibalism).

• To reduce egg breakage, a protection of egg collection belt is suggested.

5.3 Conventional cages

• To modify adjacent standard cages (30cm x 45cm) the remove every second side panel is recommended. This is simple adjustment to satisfy new caged bird welfare requirements up until 2008. Larger cages provided more freedom of movement than smaller cages.

• To reduce the opportunity for birds to bill up the feed and cause feed wastage weldmesh feed, protectors into the troughs are recommended to be insert.

• To reduce aggressive behaviours in cages light intensity throughout the whole shed should be reduced.

• To reduce heat stress alleviation the installation of a reticulated chilled water system running through all the nipple lines is recommended.

• In heat wave days (hottest part of summer) feeding after 8.00am should be avoided by using midnight feeding in order to improve feed consumption and maintain egg size.

• It is recommended that fans be placed on the southern side of the shed which is the coolest side. This would help reduce the intake of northerly hot air into the shed by creating a positive pressure at the northern wall.

5.4 Controlled environment (*Euro-vent*) cages

• A reduction of the nutrient density of diet for the controlled environment birds is recommended to prevent overweight with considerable amounts of body fat in the body cavities and liver.

• Use of minimum light intensity (10 lux – 40lux) may reduce mortality.

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Plain English Compendium Summary

Project Title:	**Assessment of Laying Hens Maintained in Different Housing Systems**
AECL Project No.:	No UQ93A
Researcher:	Prof Wayne L. Bryden and Dr Geoff D. Stewart
Organisation:	University of Queensland, School of Animal Studies
Phone:	(07) 5460 1257
Fax:	(07) 5460 1444
Email:	w.bryden@uq.edu.au
Objectives	To assess the effects of different housing systems on the production, physiology and behaviour of laying hens.
Background	Following international developments and public debate there have been concerns about the impact that cages have on some aspects of the laying hen welfare. In 1990 the Australian Senate recommended a consideration of the banning of laying cages once viable alternatives with welfare advantages and suitable to Australian conditions are developed. Currently, approx. 9% of hens are housed in range systems, 6% are in barns, and 85% of hens are housed in cages in open sided or controlled environment sheds. All systems in use have their strengths and weaknesses with respect to health and welfare of hens. There is a lack of scientific data to inform the industry and public about the advantages/disadvantages of each housing system.
Research	The assessment of production, physiology and behaviour of hens housed in five different housing systems: free range, barn, conventional cages (with 3 and 6 birds/cage) and controlled environment cages, represented by 3 replicates for each system was conducted concurrently for 52 weeks. The diet and management of birds were comparable for all assessed systems.
Outcomes	It was indicated that housing system has diverse influences on the performance traits, physiology, and behaviour of laying hens. There were significant differences in mortality, blood cell response and behaviour of hens, though birds in conventional 3 birds/cage system achieved the highest performance. Hens in conventional cages demonstrated higher production than free range and barn hens, though the health and physiological indices of hens in free range were better than barn and caged hens. As compared to all cages and free range, hens in barn had shown the lowest production and the highest mortality. The controlled environment cages did not show any specific influence on production and hen welfare.
Implications	The project has shown that different housing systems offered hens different ability to respond to environment and maintain their biological activities, while health and welfare might have been compromised.
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