LAYER STRAINS FOR ALTERNATIVE SYSTEMS

A report for the Australian Egg Corporation Pty Ltd

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July 2005

AECL Publication No 05/02
AECL Project No DAQ-283A

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ISBN 1 920 835 21 0
ISSN 1440-6845

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Published in July 2005

Foreword

Commercial non-cage egg production systems currently represent only a small proportion of the egg market however the free-range and barn poultry industries in Australia are expanding as consumer demand for non-cage eggs increases. Public concerns for poultry welfare, and a market demand for eggs produced under more “natural” conditions, have put pressure on the Australian poultry industry to consider alternative systems for housing layers (Macindoe, 1987). The growing demand for non-cage eggs is due to consumer concern for poultry welfare, and it is this welfarism that determines the characteristics of alternative production systems. These systems must therefore not only be practical and economically viable but must comply with the standards set down by organisations representing welfare-conscious consumers, such as the Royal Society for the Prevention of Cruelty to Animals (RSPCA), Animal Liberation and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ).

In Australia, particularly in Queensland, moderate climatic conditions and low land prices appear to be favourable for less intensive systems of production. Ordinary barns and free-range systems, both of which are currently in use here, are obvious choices for consideration as alternatives to cages.

The aim of this project is to provide information on the suitability of current commercial layer strains for alternative (non-cage) management systems. This will be achieved by conducting two concurrent 12-month trials to compare the strengths and weaknesses of three popular brown-egg strains when housed in barn and free-range conditions. The main value of the project will consist in providing information on performance and behavioural characteristics and raising confidence to use a particular strain when husbandry procedures appropriate for that strain are employed.

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

This report is an addition to AECL’s diverse range of research publications.

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James Kellaway
Managing Director
Australian Egg Corporation Limited

Acknowledgments

Thank you to Kerry Barram, Maxwell Kemsley, Paul Kent, Robert Jones and Gavin Jones at the Poultry Research and Development Centre, Queensland Department of Primary Industries and Fisheries, Alexandra Hills their valuable assistance during the completion of this trial. Thanks also to the biochemistry staff at Animal Research Institute, Yeerongpilly, for conducting chemical analysis of feed ingredients used in the project.

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Commercial non-cage egg production systems currently represent only a small proportion of the egg market however the free-range and barn poultry industries in Australia are expanding as consumer demand for non-cage eggs increases. The free-range industry represents an estimated 250 producers (1 in 4 commercial egg producers in Australia) with market share of 5.5%, and barn, 2.5%. The industry regards this as a niche market for specialty eggs attracting a premium price, rather than as a method of production inspired by producer concern for poultry welfare. Producers whose main business is cage-egg production in fact supply much of the demand for non-cage eggs.

Following the recent ARMCANZ directive, the Australian egg industry is under some pressure to develop viable alternative systems. Although it appears that conventional-style cages cannot be completely phased out until 2020 at the earliest, farmers with older-style cages will be forced to re-capitalise before 2008. At this time they may consider reinvestment in cages to be a high-risk option and will settle for an alternative system (or leave the industry). Even now, many existing producers, as well as new entrants to the industry, consider investment in cages to be too risky.

In Australia, particularly in Queensland, moderate climatic conditions and low land prices appear to be favourable for less intensive systems of production. Ordinary barns and free-range systems, both of which are currently in use here, are obvious choices for consideration as alternatives to cages. Barn hens are housed on deep litter in secure, weatherproof sheds. While they are provided with ample water, feed, ventilation, space and nesting boxes in accordance with the Model Code of Practice for the Welfare of Animals - Domestic Poultry (4th Ed), they do not range out of doors. Birds in free-range systems are housed in sheds and have access to an outdoor range (Model Code of Practice for the Welfare of Animals: Domestic Poultry 4th Ed). This is a traditional system for egg production which still today has the vision of 'farm fresh eggs' associated with it, where hens can wander at will over green pastures with no environmental restrictions (Kilgour and Dalton, 1984).

The suitability of current commercial layer birds for alternative production systems is affected by various factors. Strain is one of the most important of these factors as it can affect flock size, nesting behaviour, production, feed intake and mortality. Within a given management system, strain of bird is an important factor affecting husbandry requirements and economic performance. This is especially true in alternative systems with their more diversified environments and correspondingly wider range of opportunities to exhibit behaviours not required in cages.

The aim of this project was to provide information on the suitability of current commercial layer strains for alternative (non-cage) management systems. This was achieved by conducting two concurrent 12-month trials to compare the strengths and weaknesses of three popular brown-egg strains when housed in barn and free-range conditions. Performance, husbandry requirements, welfare aspects and economics of the strains was compared. Cage birds were kept for purposes of comparison. The main value of the project consists in providing information on performance and behavioural characteristics and raising confidence to use a particular strain when husbandry procedures appropriate for that strain are employed.

Equal numbers (1516) of Isa Brown, Hyline Brown and Hisex Brown day-old pullets were obtained from hatcheries on the same day and housed in floor pens. The birds were brooded and reared on the floor in accordance with the hatchery recommendations applicable to each strain. All birds were housed in the experimental (barn and free range) accommodation by approximately twelve weeks of age. The final configuration of the barn was six pens of 200 birds and three pens of 500 birds. This arrangement is a less satisfactory experimental design but provides more "realistic" conditions. There were two 200-bird replicates and one 500-bird pen of each strain in a randomised block design. The slatted areas (Big Dutchman® plastic slats) comprised one third to one half of the total floor area. The rollaway nests were similar in shape and size to most current automatic colony nests. They were

made of tin and were provided with Astroturf® floor coverings. The free-range paddock was divided into six fenced areas arranged in two blocks of three. Each block contained a shelter divided into three pens, each giving access to one of the three outdoor areas. Each of these free-range units accommodated 300 birds at a stocking density of approximately 7 birds/m^2 inside the shelter and 1250 birds/Ha outside. There were two 300-bird replicates of each strain in a randomised block design. The rollaway nests were similar in shape and size to most current automatic colony nests.

From 18 weeks of age, egg production and mortality were recorded daily with egg weights recorded fortnightly. Numbers of eggs laid in each nest and in various zones (floor, slats, paddock etc) were recorded, including numbers of cracked and blood stained eggs. Every four weeks feed intake was recorded and bodyweight, feather condition, foot and claw condition, egg specific gravity and yolk colour were recorded at three-monthly intervals. Temperature and humidity were continuously logged inside and outside the buildings (TINYVIEW® Gemini Data Loggers) and a 16-hour lighting regime were used.

Free-range and barn systems both had heavier egg weights (average 62.7 grams and 62.1 grams, respectively) than cage (average 60.5grams) throughout the trial. Isa had the heaviest eggs in the barn and free-range systems, followed by Hyline, and HiSex with the lightest. Beak trimming in the barn had no effect on egg weight.

Cage birds had the highest egg production (average 75.8%) during the trial when compared to barn and free-range birds (average 66.1% and 64.3%, respectively). In the barn system, Hyline had the highest egg production followed by Isa and HiSex, while in the free-range system, Isa had the highest egg production followed by HiSex and Hyline. According to the layer management guides for each strain, production should have been over 80% by 23 weeks. Cage birds reached 80% production by 33 weeks. In the barn, Hyline reached 80% by 41 weeks, Isa by 49 weeks and HiSex never reached 80% production. In the free-range system, Hyline reached 80% by 45 weeks, Isa by 41 weeks and HiSex by 41 weeks. However because extensive production systems were in use the productive output will vary from published standards. Beak trimming in the barn had no effect on egg production.

Free-range had the highest percentage of blood stained eggs (average 3.0%) during the trial, followed by barn and cage (average 2.7% and 0.6%, respectively). Both barn and free-range percentage of blood stained eggs increased from week 37. When strains were compared within system, Isa had the lowest blood stained eggs in the barn and the highest in the free-range, while HiSex had the highest in the barn and the lowest in the free-range. Birds that were beak trimmed had a lower percentage of blood stained eggs when compared to non-trimmed birds in that barn, which gradually increased towards the end of the trial. Directly after beak trimming, non-trimmed birds showed a dramatic increase in the number of blood stained eggs. No differences were found with yolk colour and specific gravity of eggs.

Cage had the lowest feed conversion ratio during the trial, with barn and free-range having similar feed conversion ratios. Isa had the lowest feed conversion ratio in the barn and free-range systems, with HiSex the highest in the barn and Hyline the highest in the free-range system. Beak trimmed birds in the barn had a lower feed conversion ratio compared to non-beak trimmed birds.

Free-range had the heaviest bird weight of the three systems, followed by cage and barn. Hyline birds were the heaviest in the barn and free-range systems, followed by Isa and HiSex. At 65 weeks, Hyline birds, according to the layer management guide, should have weighed 2000 grams and in the barn weighed 2045grams and 2135 grams in the free-range. Isa birds should have weighed 1950-2050 grams at 65 weeks of age and in the barn weighed 1969 grams and free-range, 2079 grams. HiSex birds 65 weeks of age should have weighed 2040 grams, and weighed 1919 grams in the barn and 1991 in the free-range. Hyline and Isa bird weights were above the layer management guide recommendations however because extensive production systems were in use the productive output will vary from published standards. Directly after beak trimming, beak trimmed birds had a lower body weight, however by week 45 they had caught up and then passed non-beak trimmed birds.

Free-range had the highest mortality of the three systems, followed by barn and cage. In the barn and free-range systems, HiSex had the highest mortality, followed by Isa and Hyline. Mortality of birds that weren't beak trimmed in the barn increased dramatically the month following the beak trim. Birds that were beak trimmed had a lower mortality than before they were trimmed for the remainder of the trial. Increased mortality in the barn and free-range systems could have been due to lower bird weight at 26-29 weeks of age, increased risk of disease due to increased contact between birds and faeces and/or vent pecking and cannibalism.

Feather condition and foot condition were scored using a 4-point scale with 1 = very severely defective part of the body and 4 = intact part of the body. Total bird feather score was similar for all three systems, with barn having a slightly lower feather score than cage and free-range (2.29, 2.50 and 2.70, respectively). Isa had the highest total bird feather score in the barn and free-range systems, followed by Hyline and HiSex. Beak trimmed birds had a higher total feather score until 65 weeks when scores were very similar. There were no differences in total foot score throughout the trial.

As the trial progressed the number of eggs laid in the nest boxes increased. Beak trimmed birds laid more eggs in the nest boxes until 57 weeks, with non-beak trimmed birds having a sharp decline in use of nest boxes directly after trimming.

Following the comparison of the strengths and weaknesses of the performance of Isa, Hyline and HiSex birds in barn and free-range systems, the present trial found that Hyline and Isa were best suited to the free-range system and Isa, to the barn system. However the mortality rates were unacceptable for all three strains in both systems. Mortality was decreased dramatically after beak trimming in the barn in the present trial however beak trimming is not wholly effective at preventing feather pecking and cannibalism, and there is continuing public concern that it may cause chronic pain. If we are to reduce the need for beak trimming in the Australian flock further research needs to be done to develop a specific strain for each system and improvement of the management procedures for current commercial breeds for use in alternate systems. Research on the nutrient requirements of bird strains used in the free range and barn systems is warranted to improve productivity and profitability.

1. Introduction

Commercial non-cage egg production systems currently represent only a small proportion of the egg market however the free-range and barn poultry industries in Australia are expanding as consumer demand for non-cage eggs increases. The free-range industry represents an estimated 250 producers (1 in 4 commercial egg producers in Australia) with market share of 5.5%, and barn, 2.5%. The industry regards this as a niche market for specialty eggs attracting a premium price, rather than as a method of production inspired by producer concern for poultry welfare. Producers whose main business is cage-egg production in fact supply much of the demand for non-cage eggs.

Margins are slim due to higher production costs, and mortality rates in free range and barn systems can be high (21% Kjaer and Sorenson, 2002, 32% Sommer and Vasicek, 2000, and 15-20% Kristensen, 1998) which are unacceptable to the producer, industry and public. Public concerns for poultry welfare, and a market demand for eggs produced under more “natural” conditions, have put pressure on the Australian poultry industry to consider alternative systems for housing layers (Macindoe, 1987). The growing demand for non-cage eggs is due to consumer concern for poultry welfare, and it is this welfarism that determines the characteristics of alternative production systems. These systems must therefore not only be practical and economically viable but must comply with the standards set down by organisations representing welfare-conscious consumers, such as the Royal Society for the Prevention of Cruelty to Animals (RSPCA), Animal Liberation and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ).

Following the recent ARMCANZ directive, the Australian egg industry is under some pressure to develop viable alternative systems. Farmers with older-style cages will be forced to re-capitalise before 2008. At this time they may consider reinvestment in cages to be a high-risk option and will settle for an alternative system (or leave the industry). Even now, many existing producers, as well as new entrants to the industry, consider investment in cages to be too risky.

1.1 Alternate Systems for Poultry Production

1.1.1 European Systems

During the 1990’s several Western European countries introduced legislation to force change from conventional cages to alternate systems of production and a wide range of welfare-orientated systems are in use (Bell, 2002). These include free range and yard systems, barns of various types, aviaries, percheries and enriched cages. Although legislation and consumer preferences vary greatly throughout the European Union (EU), in general it is probably true to say that free-range eggs are still regarded as a niche market, while aviaries and enriched cages have been developed in direct response to animal welfare legislation.

Most barn systems are based on the original concept of deep litter with hens living on one level (Bell, 2002). To increase the efficiency of the housing, ‘aviary’ type systems are being more widely adopted as it allows a greater number of birds to be placed in a shed. Aviaries endeavour to maximise stocking densities in order to minimise capital cost and enable efficient environmental control. The aviary is essentially a super-intensive type of barn, making use of vertical space by having several levels of nests and wire or slatted platforms equipped with feeders and drinkers. The high densities, however, tend to be associated with performance problems and poor operator environment. Production results achieved are below those for cages, partly due to the social pressures on the birds, which typically give higher mortalities and lower egg production (Bell, 2002). Although now in commercial use, enriched cages are still in the development phase. In the UK it has been said that the standards set down for enriched cages will make them impractical, as their high capital cost will not be offset by lower running costs and improved efficiency of production (these standards include 750cm2 per bird and provision of nests, scratching zones, perches and claw abrasion devices).

In Australia, particularly in Queensland, moderate climatic conditions and low land prices appear to be favourable for less intensive systems of production. Ordinary barns and free-range systems, both of which are currently in use here, are obvious choices for consideration as alternatives to cages. Unfortunately the husbandry standards for these systems vary between States and organisations.

1.1.2 Barn System

Barn hens are housed on deep litter in secure, weatherproof sheds. While they are provided with ample water, feed, ventilation, space and nesting boxes in accordance with the Model Code of Practice for the Welfare of Animals - Domestic Poultry (4^{th} Ed), they do not range out of doors. Of the alternative systems available, the barn system is probably the most easily adopted in Australia, in part because of the lower financial risk compared to some other more sophisticated alternative systems, industry has considerable experience with similar systems that are used in Australia for both broiler and layer breeders and because of some similarities to traditional 'back-yard' production (Barnett, 1998, 2000).

The barn system appears to have the potential to meet the requirements for efficient production while allowing a wide range of behaviours. In the longer term the barn system may be the strongest competitor to cages as the major method of production. Barns offer the main advantages of both the cage system (control, protection and economy) and free range (ample freedom of movement and behaviour, wide public acceptance) and, if well designed, may avoid many of the disadvantages of both these systems and other alternatives. However, there are some areas of design and management that need to be improved, particularly in relation to nests, mortality and operator environment.

1.1.3 Free-range System

Free range is the system most actively supported by welfare groups. Birds in free-range systems are housed in sheds and have access to an outdoor range (Model Code of Practice for the Welfare of Animals: Domestic Poultry 4^{th} Ed). This is a traditional system for egg production which still today has the vision of 'farm fresh eggs' associated with it, where hens can wander at will over green pastures with no environmental restrictions (Kilgour and Dalton, 1984). Regardless of the fortunes of other systems of production, demand for free range eggs is likely to increase gradually so that they will eventually become a significant part of the Australian egg market.

Behavioural problems are few in this system because of the unrestricted space given to the birds, which allow low-ranking birds to escape molestation (Kilgour and Dalton, 1984). Feather pecking can arise to such levels where beak trimming may be needed (Kilgour and Dalton, 1984). However from the production point of view free range is the most labour intensive system and generally the least efficient, and it presents the greatest exposure to disease, predators and extreme weather conditions.

Egg production is lower and feed intake is higher under current free range conditions than in cage systems for a number of reasons, including different environmental challenges, energy requirements, strains and husbandry. Large-scale free-range production may also be environmentally unfriendly. Shed mobility would better utilise land, but a system that combines this with the essential features of large-scale commercial production, such as automatic feeding and egg collection, has so far not been invented. Little research has been done on free-range production, however, and the long-term economic and environmental sustainability of this system is in doubt.

1.2 Alternate System Management Issues

The suitability of current commercial layer birds for alternative production systems is affected by various factors. Strain is one of the most important of these factors as it can affect flock size, nesting behaviour, production, feed intake and mortality.

1.2.1 Strain

Within a given management system, strain of bird is an important factor affecting husbandry requirements and economic performance. This is especially true in alternative systems with their more diversified environments and correspondingly wider range of opportunities to exhibit behaviours not required in cages. A wide selection of strains is now available and many producers believe that some of these are more suitable than others for barn and free-range production under Australian conditions. Strains may differ in behavioural traits such as feather pecking, foraging activity, flightiness, broodiness and inclination to lay in nest boxes. These differences have repercussions both for the welfare of the birds and the manageability of the system. Propensity to cannibalism is especially important as beak trimming is prohibited in some accreditation schemes for alternative systems. Strains may also differ in productivity under extensive conditions, and these differences may not follow the same trends that occur in cages.

Although performance criteria of some of the currently popular strains have been compared in cages (e.g. Nolan *et al*, 1997), there are no general comparisons of current strains under free range and barn conditions in Australia. The need for this information has been affirmed, especially by producer organisations, in phone communications and correspondence with this research centre. The issue was also raised at a Production Systems Workshop (RIRDC 1998) where discussions raised the point that "There is a lack of information on the suitability of newly available strains of layers to alternative production systems". The guidelines published by the Free Range Poultry Association of Queensland recommend that "farmers running birds in a range environment should choose carefully the strain of bird.... By choosing more docile strains potential outbreaks of cannibalism are significantly reduced". The association is particularly keen for research on strain comparisons to be carried out. Barnett and Newman (1997) state that birds have been selected overseas for reduced cannibalism and low mortality without a requirement for beak trimming. "If these birds become available commercially, it would obviously be of value to import and trial them under Australian conditions."

1.2.2 Flock Size and Density

While cage housing imposes a particular spatial organisation, alternative systems in most cases provide hens with the opportunity to space themselves in relatively unconstrained ways (Appleby and Hughes, 1991). In a review of research on the behaviour of hens in alternative housing systems, Craig and Adams (1984) infer that "conclusions relative to social behaviour, derived form smaller flocks (up to 100 hens) are likely to be valid also in much larger flocks." Their conclusion is based on observations (of various researchers) that "adult fowls tend to stay in relatively restricted areas within larger pens and flocks." Hens may still choose on occasion to organise in dense aggregations, or to use the available space incompletely (Appleby and Hughes, 1991). This provides some support for the design of the proposed trials and also suggests that flocks in large pens might function better when resources are evenly distributed within small zones.

Carmichael *et al*. (1999) observed Isabrown laying hens in a perchery in 10 pens with four different stocking densities and found that individual birds used about 80% of the pen volume available and did not limit their movement to small areas. Activity-related behaviour (moving, standing) was affected by crowding: as density increased, there was a decrease in the number standing. Resting and feeding behaviour was not density dependent and a low incidence of both aggression and damaging pecking was observed (Carmichael *et al*., 1999).

1.2.3 Nesting Behaviour

All systems alternative to cages provide access to nests and there is now much evidence that this meets an important need of laying hens (Appleby and Hughes, 1991). Not only do hens deprived of nests show frustration behaviour during the pre-laying period, but also hens near oviposition are strongly motivated to reach a nest site and discriminate clearly in favour of a preferred nest type (Appleby and Hughes, 1991).

Studies of nesting behaviour have focused on factors affecting the hen's choice between floor sites and nest boxes. Nest boxes are invariably located above the ground, so the birds must perch or move up to a slatted area to gain access to them. The ability to do so is affected by genetic factors, housing conditions, nest box type and position and especially rearing conditions and training (Appleby, 1984). The reduction of floor eggs depends on a combination of the right strain and appropriate equipment and husbandry. The design of nest boxes is discussed by Finger (1998), who concluded that colony rollaway nests with Astroturf®-covered, springy floors and automatic night-time ejectors provide the best combination of features at reasonable cost.

Broodiness is a problem with some strains in alternative systems. As the heritability of broodiness is low, it is unlikely that much progress in reducing broodiness could be achieved without limiting genetic improvement in other traits (Nimruzi, 1999).

1.2.4 Production

A few recent unreplicated Australasian studies (Barnett, 1999; Lu and Dingle, 1999; Thomas *et al*, 2000) indicate that hen-day egg production is similar in barns and cages but hen-housed egg production is lower owing to higher mortality in barns. Feed intake is generally higher in barn and free-range systems and floor eggs are a persistent problem. These results and the experience of local producers agree with overseas experience and studies which indicate that, on average, barn and free range birds produce fewer eggs, have higher mortality and consume more feed than birds in cages. On the other hand under good management the performance of current brown egg strains in alternative systems can be excellent. The Isabrown management guide gives an example of a free-range flock of 3,680 birds that produced a hen-housed average of 3,117 in 56 weeks with 2.74% mortality. On free range there are also opportunities for cutting feed costs by providing good pasture and by feeding whole grains, as with other systems. (Dingle, 1998).

Keeling *et al* (1988) studied the performance of free range hens housed in a polythene shelter in Scotland. In 364 days the hen-day egg number was 312.6, but due to the 15.5% mortality rate the hen-housed number was 296. As might be expected in a cold climate, feed intake was high (137g/d). Three quarters of the mortality was due to cannibalism, which was highest during hot weather towards the end of the laying period. Several studies (e.g. Siegel, 1959; Fox and Clayton, 1960; Kinder and Stephenson, 1962; Petersen, 1981 cited by Craig and Adams, 1984) indicate that production declines as floor space in deep litter houses is reduced from around 3000 cm^2/bird and/or group size is increased.

1.2.5 Feed Intake

Free-range birds obtain some of their food supply from the range, however it is generally less nutritious than the feed given to cage birds (Dingle, 1998). Hence the compound feed provided for free-range birds might need to be a more concentrated mix of nutrients than for cage hens (Dingle, 1998). Although birds on the floor, particularly on free range, consume more feed than birds in cages, this increase is presumably in response to a greater requirement for energy resulting from increased activity and the lower temperatures generally prevailing in non-cage environments. The provision of a high energy, low protein diet can reduce the cost of feed (Thear, 1990).

Thomas *et al*. (2000) found that feed intake was influenced by housing system when comparing layers in cage and barn systems. Cumulative average feed intake from 20 to 71 weeks was higher in the barn-housed birds. The feed conversion ratio to 71 weeks in the barn and cage systems was 2.36 and 2.25, respectively. Feed conversion ratios may therefore be poorer and feed costs greater in free-range systems (Dingle, 1998).

1.2.6 Mortality

Higher mortality in barn and free-range systems compared to cage systems can be due to increased disease risks and cannibalism. Free-range birds are also at risk from predators.

The advantage of greater behavioural expression in alternative systems is limited by behavioural problems that negatively influence animal welfare (Pötzsch *et al*., 2001). Feather pecking is one of the most serious behavioural problems in commercial laying hens, occurring in both caged birds and birds kept in floor systems. Feather pecking is the pecking at, or plucking feathers from, a conspecific (Pötzsch *et al*., 2001). It is characterised by poor quality plumage, patches of feather loss and damage to the skin (Pötzsch *et al*., 2001). McAdie and Keeling (2000) suggest that feather pecking is a problem particularly in loose-housing systems where many hens can be affected by only a few feather peckers. Feather pecking can become an even larger problem if it spreads throughout the flock. In the flock feather pecking may result in increased mortality, decreased egg production and increased food consumption (Appleby *et* al., 1992, Pötzsch *et al*., 2001). Heat loss from defeathered birds can lead to more than 40% higher energy needs or 27% greater food consumption (Bilčík and Keeling, 1999).

Feather pecking can also be considered a welfare problem because it has been suggested that it can lead to cannibalism (Allen and Perry, 1975). Appleby *et al*. (1992) agrees that cannibalism sometimes follows on from feather pecking, for example when exposed skin is injured, but it more often arises individually. Gunnarsson *et al*. (1999) found no significant correlation between cloacal cannibalism and feather pecking agreeing with previous findings in the literature that feather pecking is separate from pecking associated with cloacal cannibalism (Hughes and Duncan, 1972). Cannibalism has been defined in many ways, the most objective describing it as the “pecking and tearing of the skin and underlying tissues of another bird” (Keeling, 1994). In hens, the most common form is vent pecking.

Hughes and Duncan (1972) found that feather and vent pecking are influenced by a large number of factors including strain effects, light, group size, diet and position effects.

2. Objectives

There are a number of reviews comparing various overseas egg production systems, particularly welfare and behavioural aspects (e.g. Craig and Adams, 1984; Elson, 1988; Kuit *et al*, 1989; Tauson, 1996), as well as an abundance of comment in the popular literature. Yet there are few reliable comparisons between cage and non-cage systems. The most rigorous studies, conducted at the Swedish University of Agricultural Sciences, Uppsala, relate to aviaries and furnished cages. Unreplicated comparisons of deep litter with cages done in Europe (e.g. Appleby et al, 1988) are unconvincing and may have little application to Australian conditions.

The aim of this project was to provide information on the suitability of current commercial layer strains for alternative (non-cage) management systems. This was achieved by conducting two concurrent 12-month trials to compare the strengths and weaknesses of three popular brown-egg strains when housed in barn and free-range conditions. Performance, husbandry requirements, welfare aspects and economics of the strains were compared. Cage birds were kept for purposes of comparison.

Increasing consumer demand for non-cage eggs, pressure from animal welfare groups and changes to legislation will encourage poultry farmers to invest in alternative systems of production. As there is no information on the suitability of aviaries and furnished cages for Australian conditions, the only options for the immediate future are barns and free range, both of which are currently used, mainly on a small scale, in all States. This project will benefit new entrants to the egg industry and producers who are considering diverting resources to alternative systems, as well as current barn and free range producers.

The main value of the project consists in providing information on performance and behavioural characteristics and raising confidence to use a particular strain when husbandry procedures appropriate for that strain are employed.

3 Methodology

3.1 Animals and Treatments

Equal numbers (1516) of Isa Brown, Hyline Brown and Hisex Brown day-old pullets were obtained from hatcheries on the same day and housed in floor pens. The birds were brooded and reared on the floor in accordance with the hatchery recommendations applicable to each strain. These recommendations include (1) feeding specified starter, grower and (if specified) pre-layer diets, (2) providing the correct lighting pattern throughout the rearing period (3) ensuring the average weight of the birds complies with the growth curve supplied by the hatchery and (4) following an appropriate vaccination schedule. Although beak trimming may be indicated as a standard procedure for some strains, for these trials it was desirable to avoid beak trimming if possible so that the strains could be properly compared in regard to adaptability to barn and free-range conditions. All birds were housed in the experimental (barn and free range) accommodation by approximately twelve weeks of age.

The barn consisted of a building of sandwich panel construction, which can operate as an open-sided barn or as a fully enclosed, controlled environment shed. During this experiment it was operated as an open-sided shed. The ideal configuration is either 24 pens of 100 birds or 12 pens of 200 birds (stocking density of approximately seven birds/m^2). The final configuration of the barn was six pens of 200 birds and three pens of 500 birds. This arrangement is a less satisfactory experimental design but provides more “realistic” conditions. There were two 200-bird replicates and one 500-bird pen of each strain in a randomised block design. The slatted areas (Big Dutchman® plastic slats) comprised one third to one half of the total floor area. The rollaway nests were similar in shape and size to most current automatic colony nests. They were made of tin and were provided with Astroturf® floor coverings. In the 200 bird pens the nests were located on one level adjacent to the slatted area and, in the 500 bird pens, the nests were on two levels adjacent to the slatted area (Figure 1). Four tube feeders were suspended over the litter area in the 200 bird pens and ten in the 500 bird pens. In the 200 bird pens the bell drinkers were suspended over the slats and, in the 500 bird pens, two bell drinkers were suspended over the slats and two over the litter area.

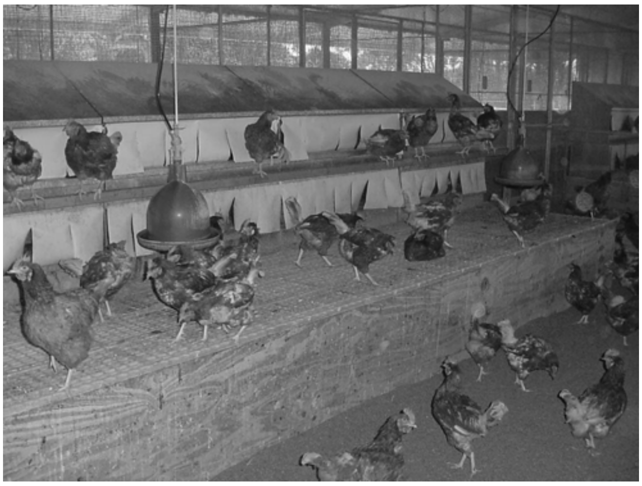

Figure 1. Nest boxes and slat area in a 500-bird pen in the barn.

The free-range paddock was divided into six fenced areas arranged in two blocks of three. Each block contained a shelter divided into three pens, each giving access to one of the three outdoor areas (Figure 2). Each of these free-range units accommodated 300 birds at a stocking density of approximately 7 birds/m^2 inside the shelter and 1250 birds/Ha outside. While the latter density is higher than the maximum recommended by some organisations, it may assist this trial by amplifying some of the possible differences between strains. There were two 300-bird replicates of each strain in a randomised block design. The rollaway nests were similar in shape and size to most current automatic colony nests. They were made of tin and are provided with Astroturf® floor coverings). Each pen contained six nest boxes with four nests on one level and two nest boxes above these. There were perches at the entrance to each nest. Six tube feeders and four bell drinkers were located above the litter in each pen.

Figure 2. Free-range shelter divided into three pens.

Some birds of each strain (110) were kept in a cage layer facility for purpose of comparison. There were two birds per cage with each strain completing one row of the shed. During lay all birds were fed the same diet, as the nutritional requirements of the strains are similar and feed intake is expected to be similar (Table 1).

Table 1. Layer diet - 28 weeks to end of lay.

Ingredient	Amount (g/kg)
Sorghum	499.347
Soybean (49%)	137.003
Sunflower (32%)	104.146
Wheat	100.000
Limestone Granular	50.000
Limestone Powder	33.505
Meat Meal (51%)	23.792
Lucerne	20.000
Tallow	10.314
Sunflower Oil	5.837
Dicalcium Phosphate	5.480
Vitamins & Minerals	3.000
Methionine	2.293
Yolk Pigment Premix	2.001
Salt	1.907
Lysine	1.199
Sodium Bicarbonate	0.179

3.2 Production Measures

From 18 weeks of age, egg production and mortality were recorded daily with egg weights recorded fortnightly. Numbers of eggs laid in each nest and in various zones (floor, slats, paddock etc) were recorded, including numbers of cracked and blood stained eggs. Total eggs for each pen were weighed (Mettler Toledo SG16001 DeltaRange®) and divided by the number of eggs per pen to determine egg weight.

Every four weeks feed intake was recorded and bodyweight, feather condition, foot and claw condition, egg specific gravity and yolk colour were recorded at three-monthly intervals. Ten percent of birds in each pen were individually weighed to determine pen bird weight (Salter 235/6 - 10kg). Feather condition, foot condition (toe pad hpyerkeratosis and bumble foot) and claw length were scored using the method as described by Tauson *et al.* (1984). This method uses a scoring system comprising the scores 1, 2, 3 or 4 points for each characteristic. The higher score implies a better health status, i.e. from score 1 (= very severely defective part of the body), to score 4 (= intact part of the body). Ten percent of birds in each pen were scored. Individual eggs were weighed in air and water (Mettler Toledo P-1200) to ascertain their specific gravity. Yolk colour was determined using a Roche® Yolk Colour Fan.

Temperature and humidity were continuously logged inside and outside the buildings (TINYVIEW® Gemini Data Loggers) and a 16-hour lighting regime was used. Husbandry records include details of procedures used (if necessary) to encourage birds to utilise the full floor or range area, perches and nests, to discourage broodiness, to reduce aggression and to control parasites. Birds were regularly examined for signs of ill health and where necessary specimens were taken for laboratory examination/culture.

3.3 Statistical Analysis

Performance and production data was analysed in four categories - strain within system, strain between systems, system and beak trim within barn. The data was not replicated therefore detailed statistical analysis could not be performed. Means and linear regressions were performed using

Microsoft ®Excel. Linear regression calculates the least squares fit for a line represented by the following equation: $y = mx + b$ where m is the slope and b is the intercept.

4 Results

4.1 Strain within System

4.1.1 Free Range

The egg weight of Isa eggs peaked at 53 weeks of age with 70 grams. This was the heaviest of the three strains with Hyline reaching 67.6 at 49 weeks of age and HiSex 66.6 at 53 weeks of age. By 33 weeks of age all layers, on average, were laying eggs heavier than 60 grams (figure 3). Over the course of the trial the average egg weight of the strains were: Isa - 63.9 grams, Hyline - 62.4 grams and Hi Sex - 61.7grams.

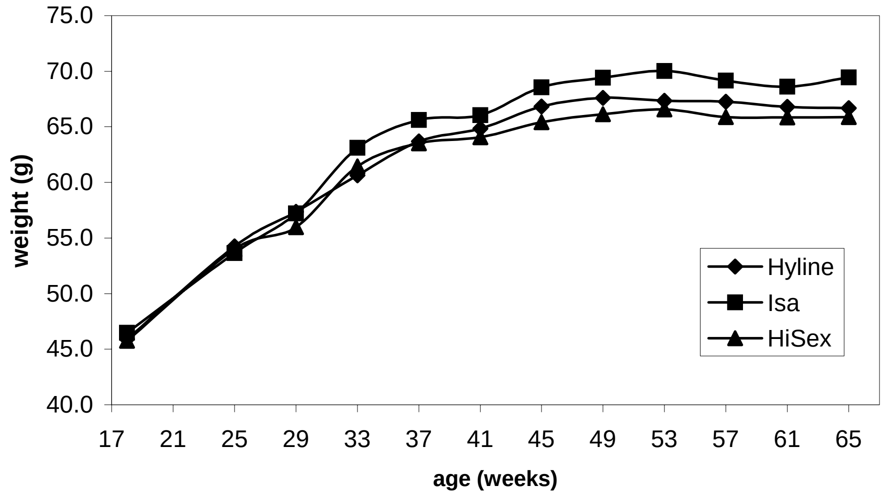

Figure 3. Effect of strain on egg weight in a free-range layer system.

Four weeks prior to egg weight peaking, laying percentage peaked for all three strains. Isa (85.5%) and HiSex (85.1%) peaked at 49 weeks of age with Hyline (82.8%) peaking at 45 weeks of age (figure 4). Hyline layers started to lay earlier than the other strains therefore had a higher overall average laying percentage over the entire trial at 63.9% compared to Isa - 58.9% and HiSex - 58.7%.

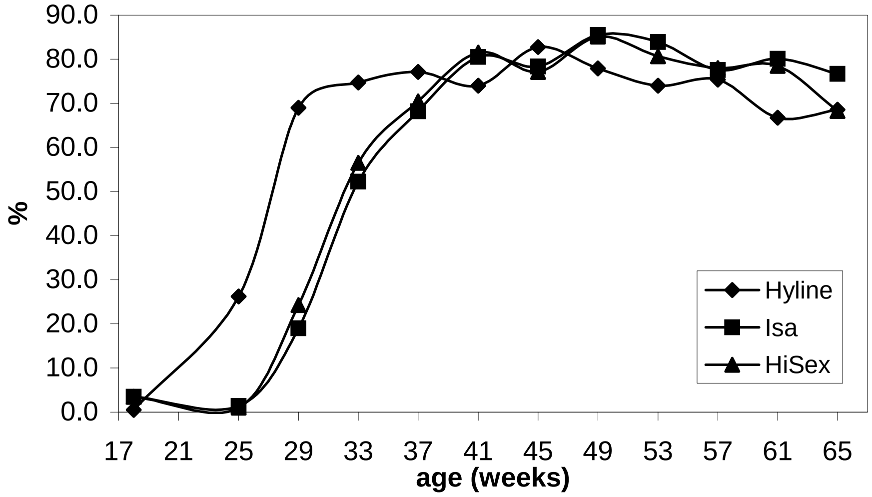

Figure 4. Effect of strain on laying percentage in a free-range layer system.

At 41 to 45 weeks of age, all strains of layers showed a dramatic increase in the percentage of blood stained eggs laid. HiSex plateaued at approximately 4% with Isa increasing to 9% (figure 5). Over the trial the average percentage of blood stained eggs laid was the highest for Isa (3.8%), followed by Hyline (2.7%) and HiSex (2.5%).

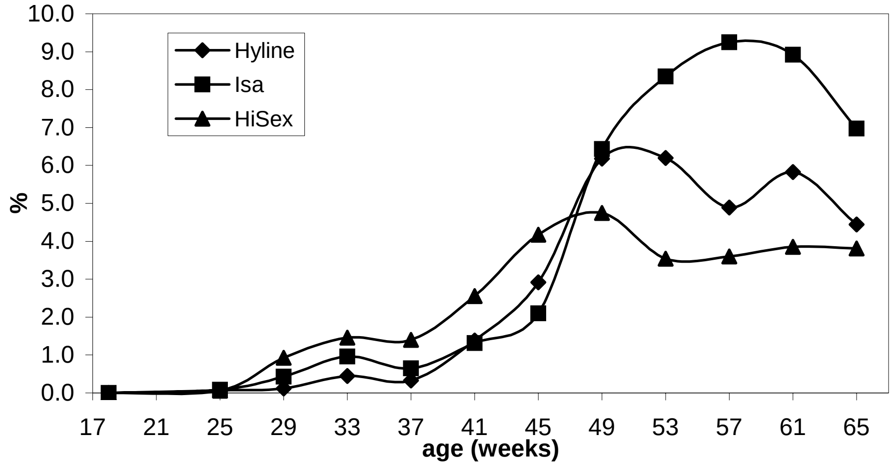

Figure 5. Effect of strain on percentage of blood stained eggs in a free-range layer system.

Strain did not have any effect of specific gravity of eggs in a free-range system (table 2). Yolk colour of the three strains in the free-range system was similar with all strains increasing from week 35 to 42 and then decreasing to week 54 (table 2).

Table 2. Effect of strain on specific gravity and yolk colour of eggs in a free-range layer system.

Strain	Specific Gravity			Yolk Colour		
Week	35	42	54	35	42	54
Isa	1.09	1.08	1.09	11.9	12.5	11.4
Hyline	1.09	1.08	1.08	12.6	13.1	11.0
HiSex	1.09	1.08	1.08	12.3	13.1	11.4

All three strains had the same average feed conversion ratio (3.0) over the entire trial when the data from month 1 (18wks to 24wks) was excluded (figure 6).

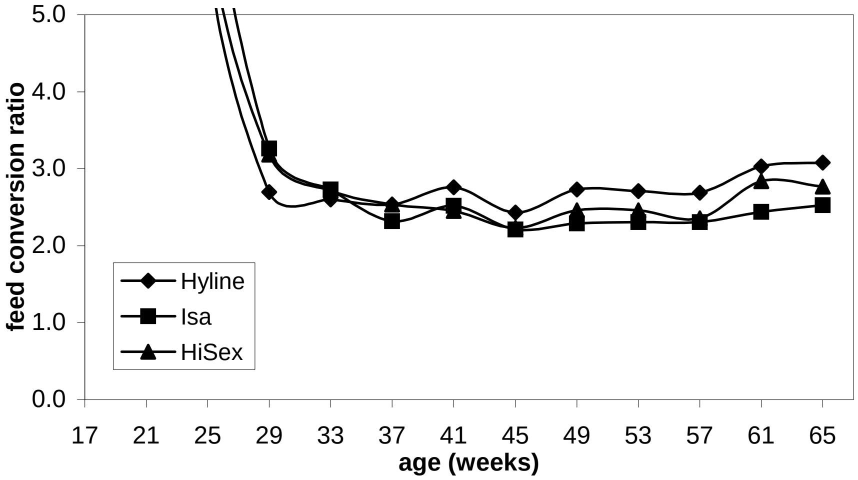

Figure 6. Effect of strain on feed conversion ratio in a free-range layer system.

Bird weight increased until the birds were 45 weeks of age. From then on the weight of the birds stabilised (figure 7). The average bird weight over the length of the trial was 1957.5 grams for Hyline, 1937.8 grams for Isa and 1850.0 grams for HiSex. The average weight of the birds from week 45 was 2104.5 for Hyline, 2057.5 for Isa and 1986.3 for Hi Sex. HiSex were lower in weight than Isa and Hyline throughout the trial.

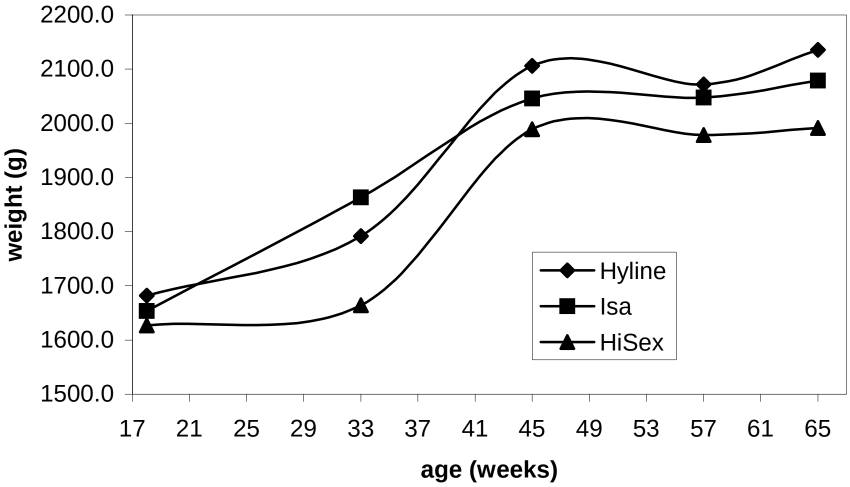

Figure 7. Effect of strain on bird weight in a free-range layer system.

HiSex mortality increased dramatically from 29 weeks to 33 weeks (3.7% to 13.2%). Isa and Hyline increased from 41 weeks of age (figure 8). HiSex mortality started to decreased after 33 weeks with all three strains decreasing dramatically after 49 weeks. Isa had the highest mortality percent over the entire trial (5.5%) followed by Hyline (5.4%) and HiSex (5.2%).

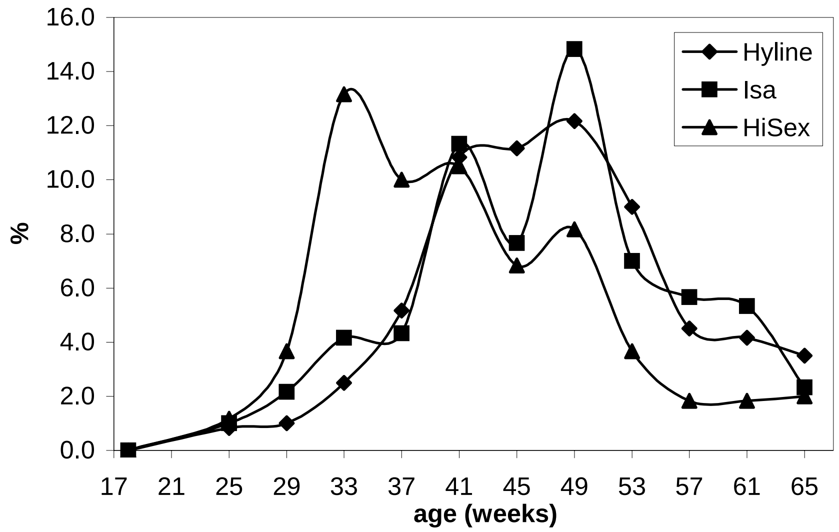

Figure 8. Effect of strain on morality (%) in a free-range layer system.

All three strains had similar total body feather scores at 18 weeks (figure 9). By the end of the trial Isa had the highest score with 2.88, followed by Hyline (2.73) and HiSex (2.50).

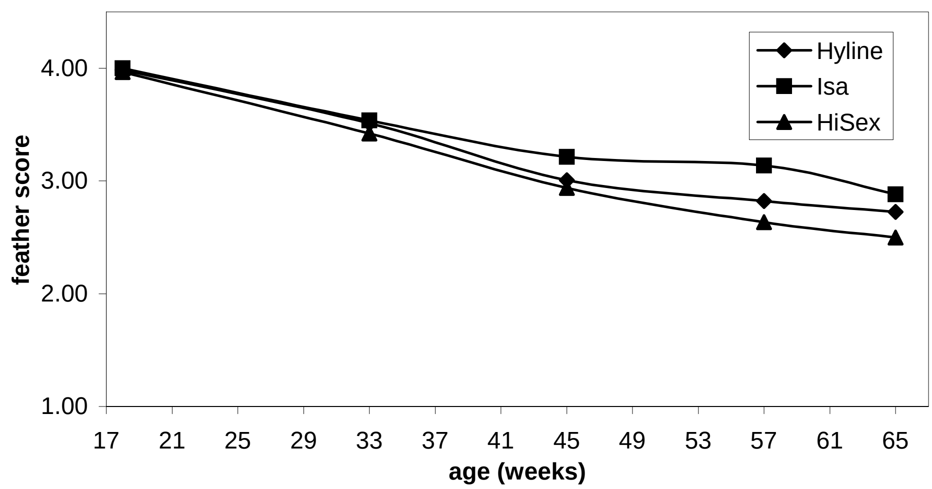

Figure 9. Effect of strain on total body feather score in a free-range layer system.

Neck feather scores were the same (4) at 18 weeks of age. Only Hyline had a score of below 3 (2.98) for part of the trial (57 weeks) however it had increased again by the end of the trial. Isa had the highest score throughout the trial with differences becoming more apparent at week 45 (figure 10).

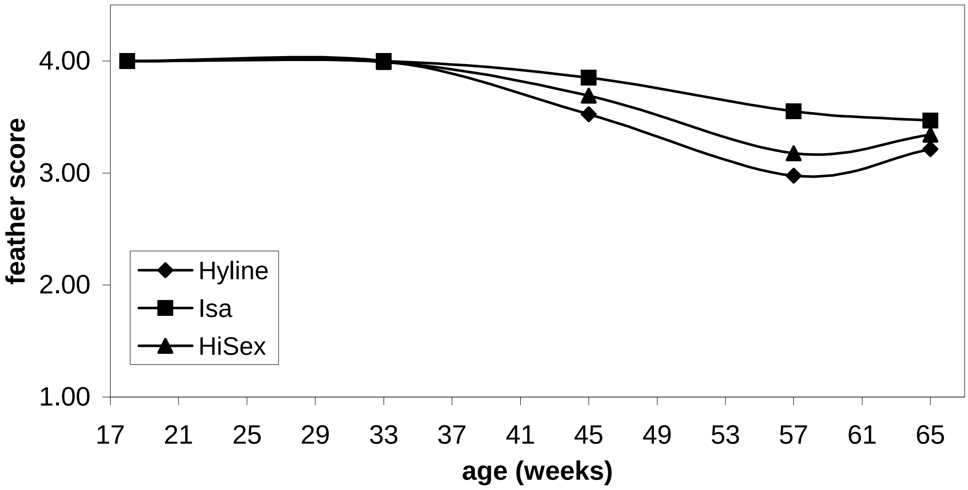

Figure 10. Effect of strain on neck feather score in a free-range layer system.

Isa had the highest back feather scores throughout the trial starting with a score of 4 at 18 weeks and finishing with a score of 1.86 at 65 weeks. HiSex started and finished with the lowest scores (3.88 and 1.40 respectively). Between weeks 45 and 57 the scores were fairly stable however dropped again at week 65 (figure 11).

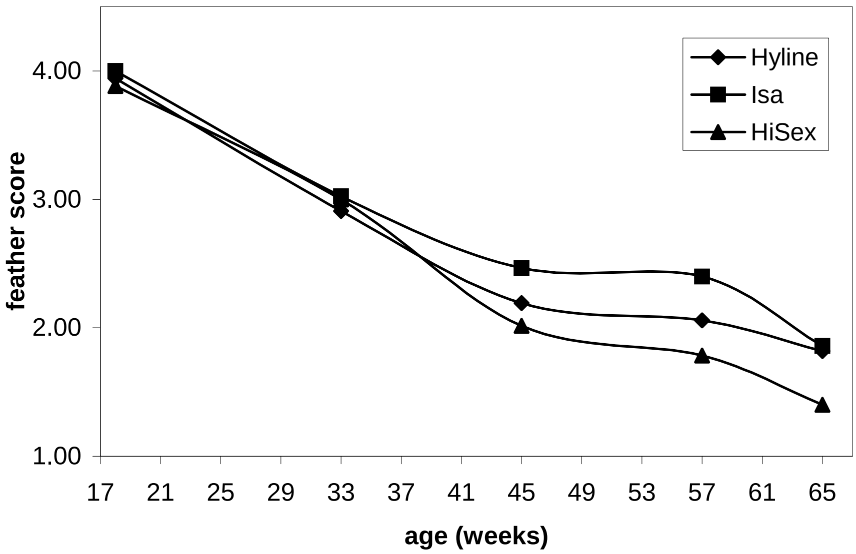

Figure 11. Effect of strain on back feather score in a free-range layer system.

All strains had a breast feather score of 4 at 18 weeks, and remained similar until 57 weeks (figure 12). At the completion of the trial Isa had the highest breast feather score at 2.98, followed by Hyline at 2.78 and HiSex at 2.48.

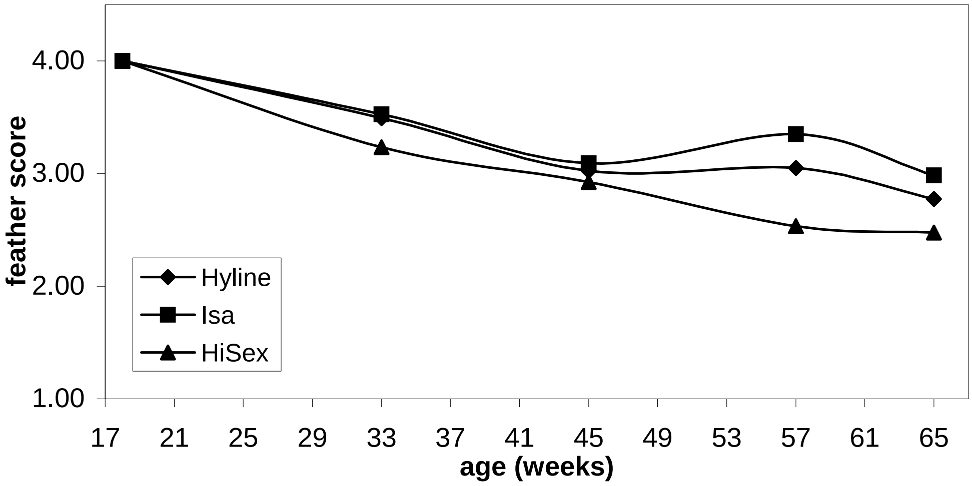

Figure 12. Effect of strain on breast feather score in a free-range layer system.

Wing feather score did not differ significantly between all three strains during the trial. All strains started on a score of 4 at 18 weeks and never went below 3.5. At week 45 HiSex score started to decrease finishing on 3.53, with Isa finishing on 3.85 and Hyline, 3.74 (figure 13).

At 18 weeks of age Isa had a tail feather score of 4, which had decreased to 2.26 by 65 weeks. This was the highest tail feather score at 65 weeks with Hyline (2.08) following and HiSex (1.75) the lowest (figure 14).

Foot score (combined toe pad hyperkerotosis, bumble foot and claw length) did not differ for the three strains for the duration of the trial. The range of values was 3.99 to 3.88 (figure 15).

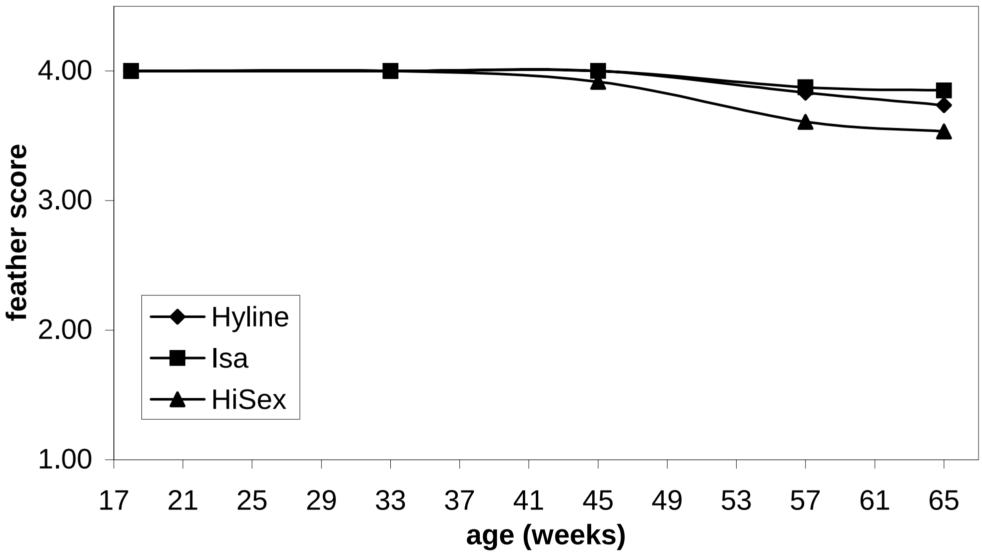

Figure 13. Effect of strain on wing feather score in a free-range layer system.

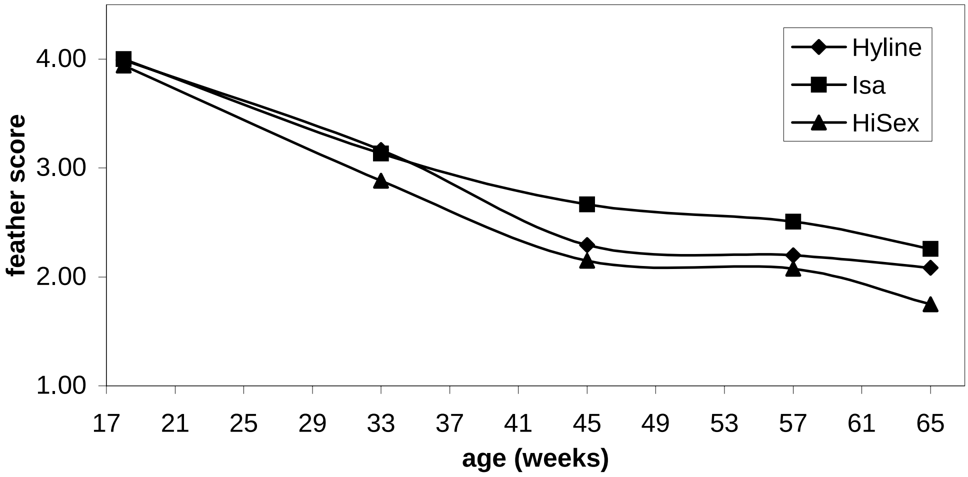

Figure 14. Effect of strain on tail feather score in a free-range layer system.

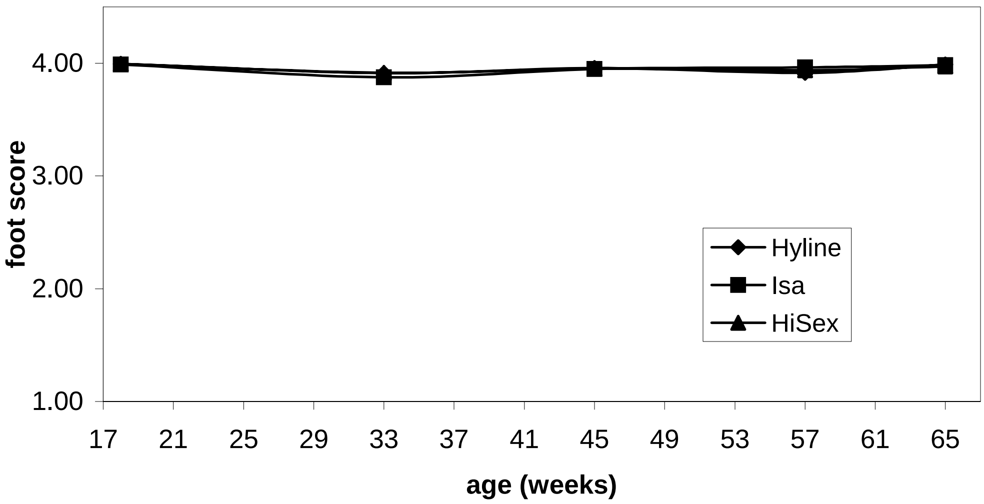

Figure 15. Effect of strain on foot score in a free-range layer system.

Linear regressions were performed to investigate the relationship between various production parameters. All of the relationships were positive, however the relationship between blood stained eggs and mortality was not strong (table 3).

Table 3. Effect of strain on relationship between blood stained eggs and mortality, blood stained eggs and egg weight, blood stained eggs and bird weight, and bird weight and egg weight. R^2 in bold are > 0.500.

Factors	Strain	Relationship	R^2
Blood Stained Eggs	Isa	+	0.109
V	Hyline	+	0.284
Mortality	HiSex	+	0.009
Blood Stained Eggs	Isa	+	0.492
V	Hyline	+	**0.550**
Egg Weight	HiSex	+	**0.745**
Blood Stained Eggs	Isa	+	**0.548**
V	Hyline	+	**0.855**
Bird Weight	HiSex	+	**0.942**
Bird Weight	Isa	+	**0.950**
V	Hyline	+	**0.820**
Egg Weight	HiSex	+	**0.655**

All three strains had a higher percentage of eggs laid in nest boxes at 18 weeks of age than 25 weeks of age. At 18 weeks Hyline laid 90.5% of eggs in the nest box compared with 76.7% at 25 weeks, Isa, 84.3% and 68.0% and HiSex, 59.4% and 53.6%. The percentages then increased until the end of the trial with Hyline having the highest percentage of eggs laid in a nest box at 95.4%, followed by HiSex at 94.7% and Isa at 88.3%. Even though HiSex started with a much lower percentage of eggs laid in nest boxes they had caught up to the other two strains by 37 weeks (figures 16 and 17).

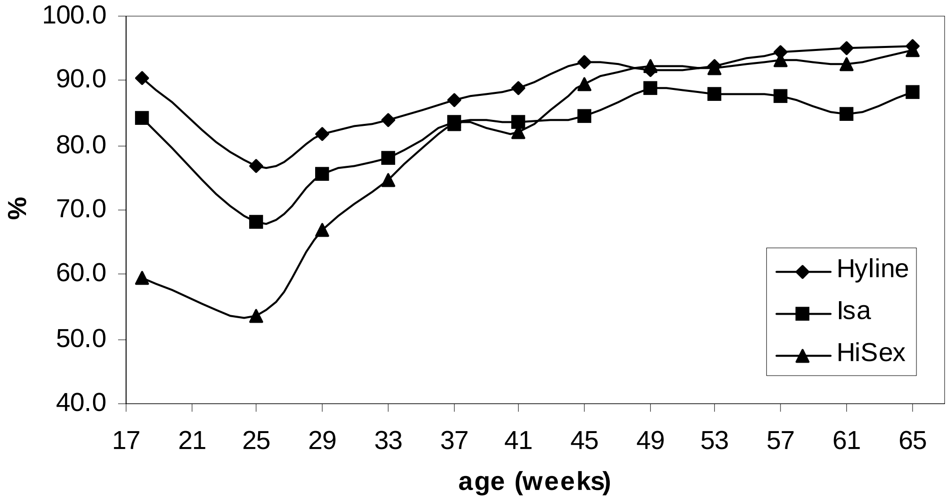

Figure 16. Effect of strain on percentage of eggs laid in nest boxes in a free-range layer system.

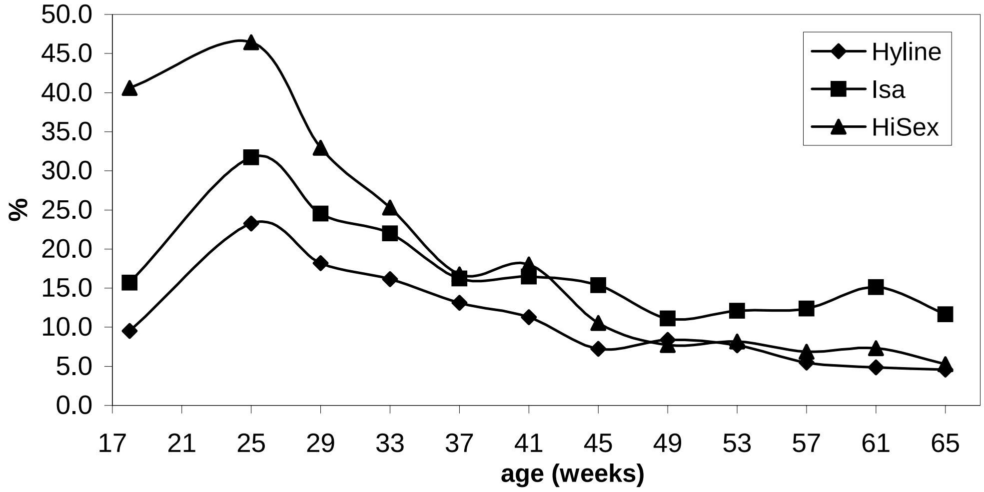

Figure 17. Effect of strain on percentage of floor eggs in a free-range layer system.

Birds were scored for production and performance factors (egg weight, laying percent, mortalities, percentage of blood stained eggs, feed conversion ratio, bird weight and total feather score) on a 3 point scale with 1 = best result for that factor (heaviest eggs, lowest mortalities etc) and 3 = worst result for that factor (lightest eggs, highest mortalities etc). In the free-range system Hyline and Isa had the lowest score therefore were equally suited to the system (table 4).

Table 4. Effect of strain on performance score in a free-range layer system (3 point scale with 1 = best result for that factor (heaviest eggs, lowest mortalities etc) and 3 = worst result for that factor (lightest eggs, highest mortalities etc).

Free-range			
Factor	**Hyline**	**Isa**	**HiSex**
Egg weight (g)	2	1	3
Lay (%)	1	2	3
Mortalities (%)	2	3	1
Blood stained eggs (%)	2	3	1
Feed conversion ratio	3	1	2
Bird weight (g)	1	2	3
Total feather score	2	1	3
Total	13	13	16

4.1.2 Barn

Egg weight was greater than 68 grams for Isa from 49 weeks, peaking at 68.83 grams at 65 weeks. Both Hyline and HiSex had eggs heavier than 66 grams from 53 weeks with Hyline peaking at 67.92 grams (53 weeks) and HiSex, 66.6 grams (65 weeks). Isa and HiSex had their heaviest eggs in the final month of the trial (figure 18).

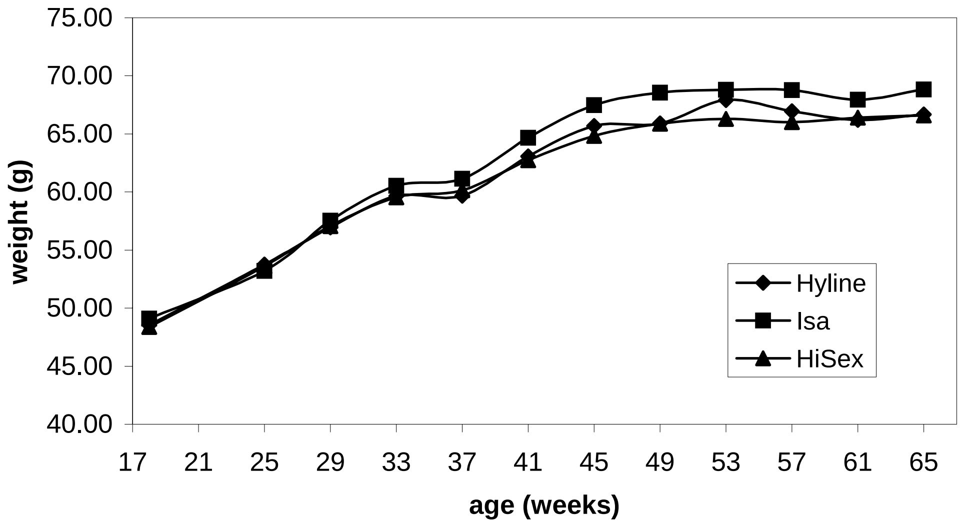

Figure 18. Effect of strain on egg weight in a barn layer system.

Both Hyline and HiSex had their peak laying percentage at 41 weeks with, 84.2% and 78% respectively. Isa peaked three months later, at 53 week, with a laying percentage of 83.1%. After week 49, Isa had the highest laying percentage (figure 19).

HiSex peaked earliest for percentage of blood stained eggs at 45 weeks, after a sharp increase during weeks 37-41, reaching 4.9%. Hyline followed, with an increase during weeks 41-45, peaking at week 49 with 6.1%. A more gradual increase was shown by Isa, peaking at week 57 with 5.0% (figure 20).

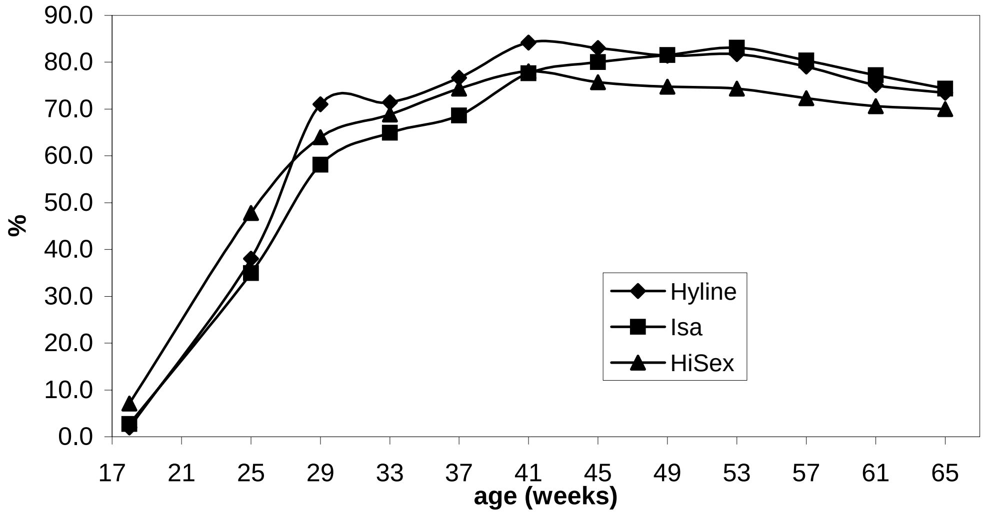

Figure 19. Effect of strain on laying percentage in a barn layer system.

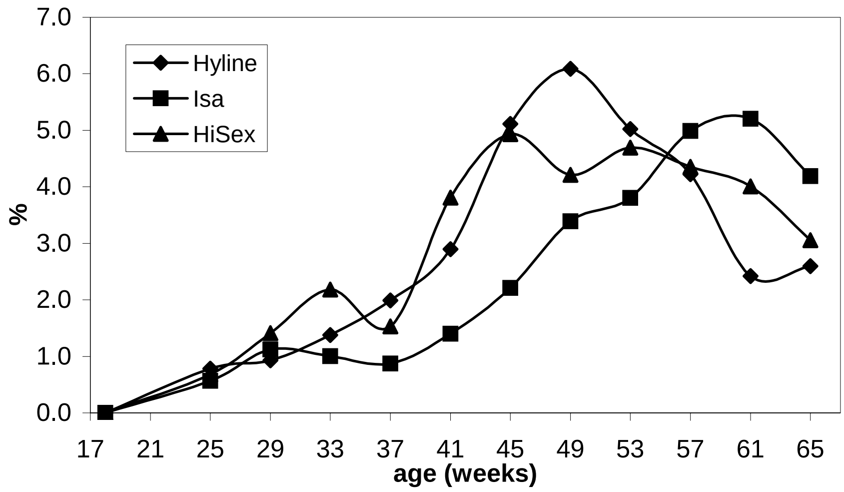

Figure 20. Effect of strain on blood stained eggs in a barn layer system.

Strain did not have any effect on specific gravity of eggs in a barn system (table 5). Yolk colour of the three strains in the barn system was similar with all strains increasing from week 35 to 42 and then decreasing to week 54 (table 5).

Table 5. Effect of strain on specific gravity and yolk colour of eggs in a barn layer system.

Strain	Specific Gravity	Yolk Colour

Week	35	42	54	35	42	54
Isa	1.09	1.08	1.09	12.4	12.5	12.0
Hyline	1.08	1.07	1.08	12.8	12.9	11.0
HiSex	1.09	1.08	1.09	12.2	12.4	10.4

Feed conversion ratio was similar for the three strains throughout the trial with HiSex the highest from 49 weeks (2.4), followed by Hyline (2.3) and Isa (2.1) (figure 21).

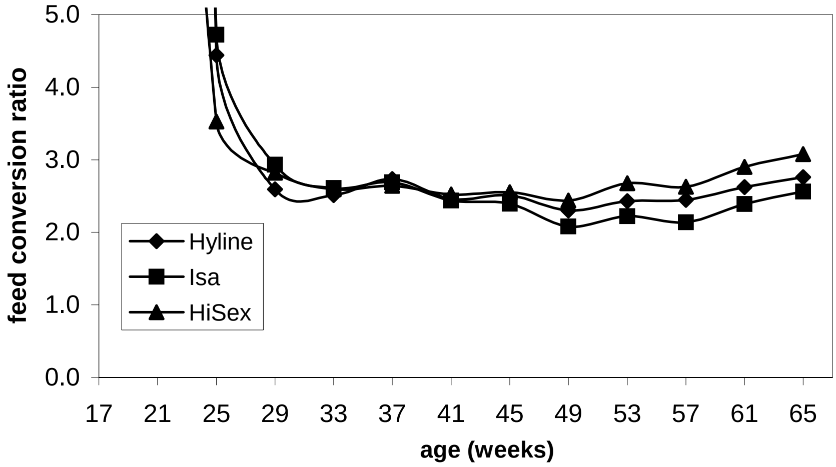

Figure 21. Effect of strain on feed conversion ratio in a barn layer system.

Hyline had the heaviest birds from 45 weeks reaching a final weight of 2045.7 grams, with Isa reaching 1969 grams and HiSex, 1919 grams. Hyline and Isa birds decreased in weight from week 57 to the end of the trial (figure 22).

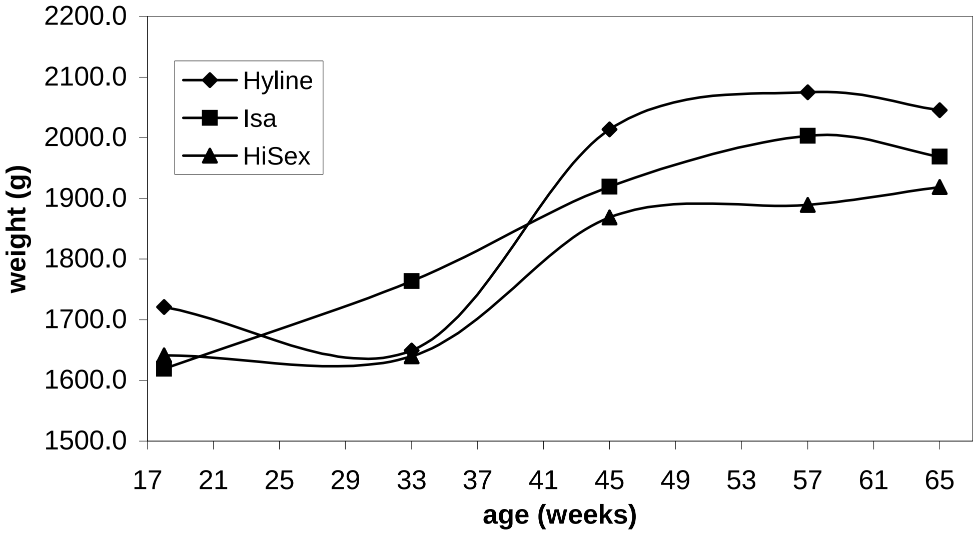

Figure 22. Effect of strain on bird weight in a barn layer system.

HiSex mortality increased dramatically from 29 weeks, from 3.4% to 8.7%. All three strains were similar at week 33 (figure 23). A decrease by all strains in week 37 was followed by an increase during the next month and then Isa and HiSex maintaining fairly steady until the end of the trial.

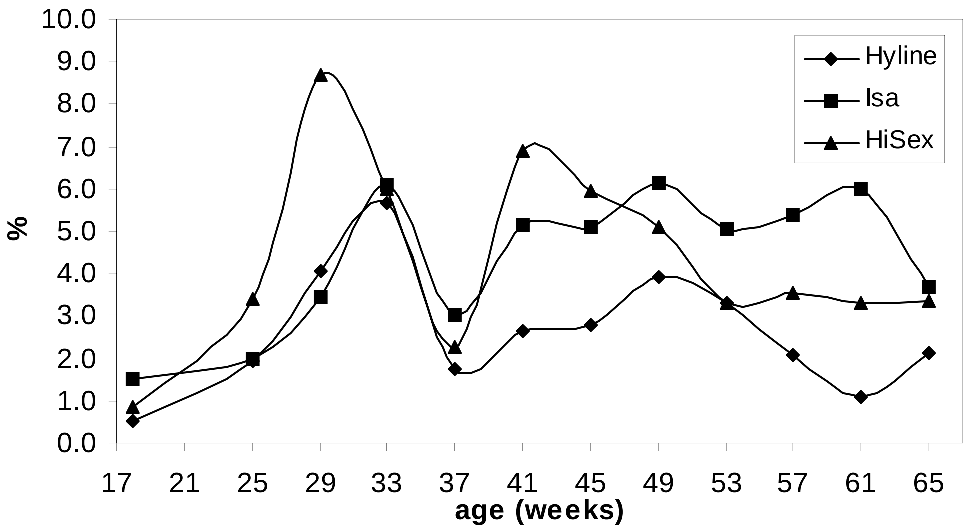

Figure 23. Effect of strain on mortality in a barn layer system.

Isa had the highest total feather score from the start of the trial, until it's completion. HiSex and Hyline had similar scores throughout the trial, with all three strains showing a gradual decline over time (figure 24). From week 45, Hyline birds had lower neck feather scores than Isa and HiSex (figure 25). However by week 57, Hyline and HiSex birds had similar scores (2.80 and 2.65, respectively), with Isa having a higher score of 3.22. HiSex and Hyline had similar back feather scores throughout the trial, with Isa having a higher score. All three strains showed a slight increase in back feather score from 57 to 65 weeks (figure 26).

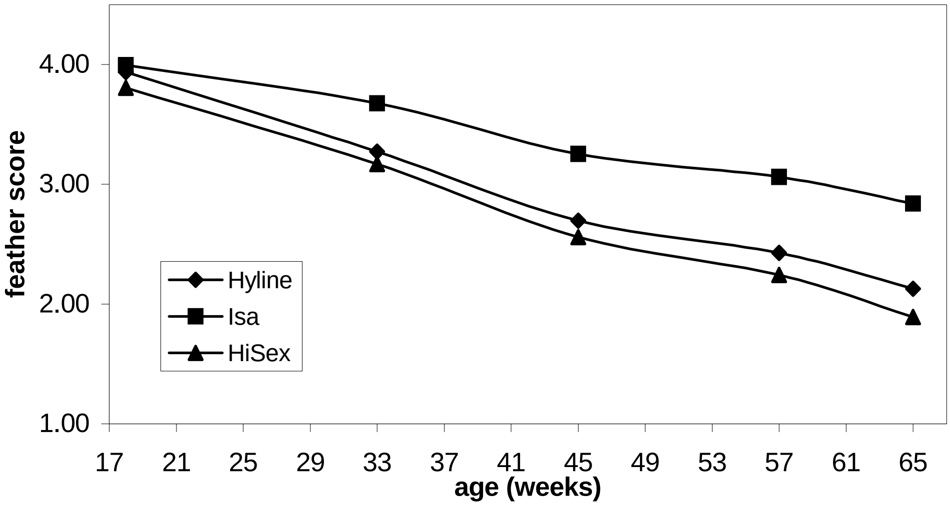

Figure 24. Effect of strain on total body feather score in a barn layer system.

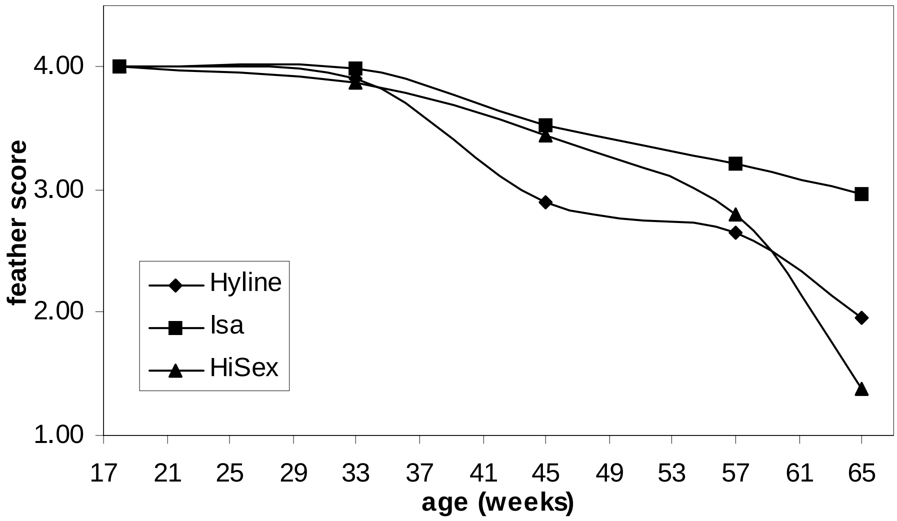

Figure 25. Effect of strain on neck feather score in a barn layer system.

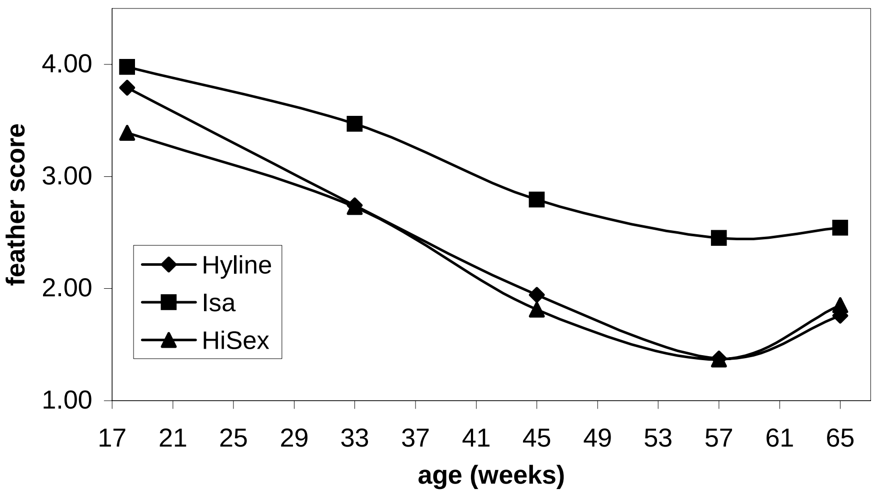

Figure 26. Effect of strain of back feather score in a barn layer system.

Isa had the highest breast feather score and HiSex the lowest throughout the duration of the trial. HiSex and Hyline had similar breast feather scores at 65 weeks (<2), while Isa had a score of 2.76 (figure 27).

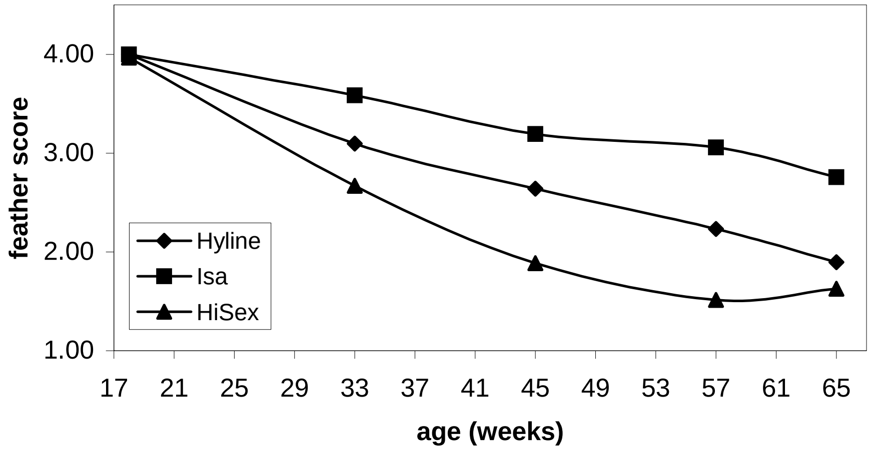

Figure 27. Effect of strain on breast feather score in a barn layer system.

Wing feather score was similar for all three strains throughout the trial (figure 28). All strains decreased from weeks 57 to 65 with Isa finishing on a score of 2.91, Hyline, 2.32 and HiSex, 2.11.

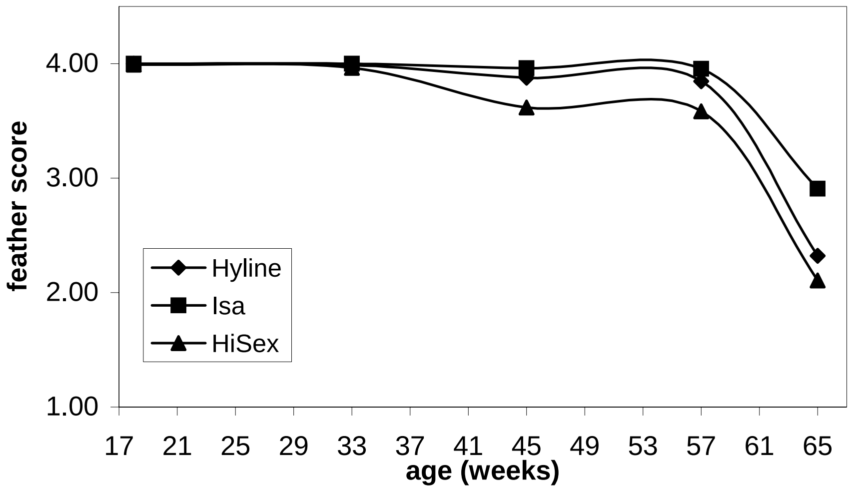

Figure 28. Effect of strain on wing feather score in a barn layer system.

HiSex and Hyline had similar tail feather scores throughout the trial (figure 29). Isa had the highest scores throughout the trial, with all three strains score increasing from weeks 57 to 65. At week 65, Isa had a score of 3.02, followed by Hyline (2.71) and HiSex (2.49).

Foot score (combined toe pad hyperkerotosis, bumble foot and claw length) did not differ for the three strains for the duration of the trial. The scores were never below 3.93 for any strain during the trial (figure 30).

Linear regressions were performed to investigate the relationship between various production parameters. All of the relationships were positive, however the relationship between blood stained eggs and mortality was not strong (table 6).

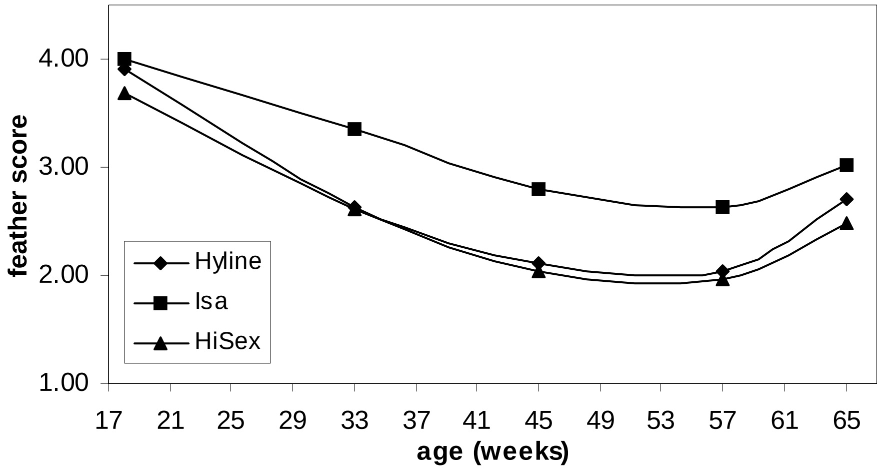

Figure 29. Effect of strain on tail feather score in a barn layer system.

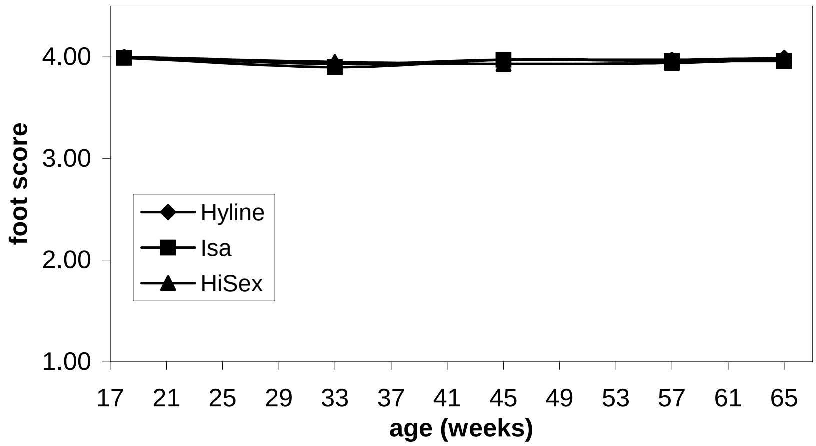

Figure 30. Effect of strain on foot score in a barn layer system.

Table 6. Effect of strain on relationship between blood stained eggs and mortality, blood stained eggs and egg weight, blood stained eggs and bird weight and, bird weight and egg weight. R^2 in bold are > 0.500.

Factors	Strain	Relationship	R^2
Blood Stained Eggs	Isa	+	0.378
V	Hyline	+	0.057
Mortality	HiSex	+	0.054
Blood Stained Eggs	Isa	+	**0.708**
V	Hyline	+	**0.681**
Egg Weight	HiSex	+	**0.841**
Blood Stained Eggs	Isa	+	**0.887**
V	Hyline	+	**0.655**
Bird Weight	HiSex	+	**0.634**
Bird Weight	Isa	+	**0.955**
V	Hyline	+	**0.629**
Egg Weight	HiSex	+	**0.728**

Isa and Hyline showed a gradual increase in the percentage of eggs laid in nest boxes throughout the trial, with Isa finishing on 97.4% at 65 weeks and Hyline 90.8%. HiSex increased with the other strains however peaked at 53 weeks with 91.7%, and finishing at week 65 on 88.9% (figure 31).

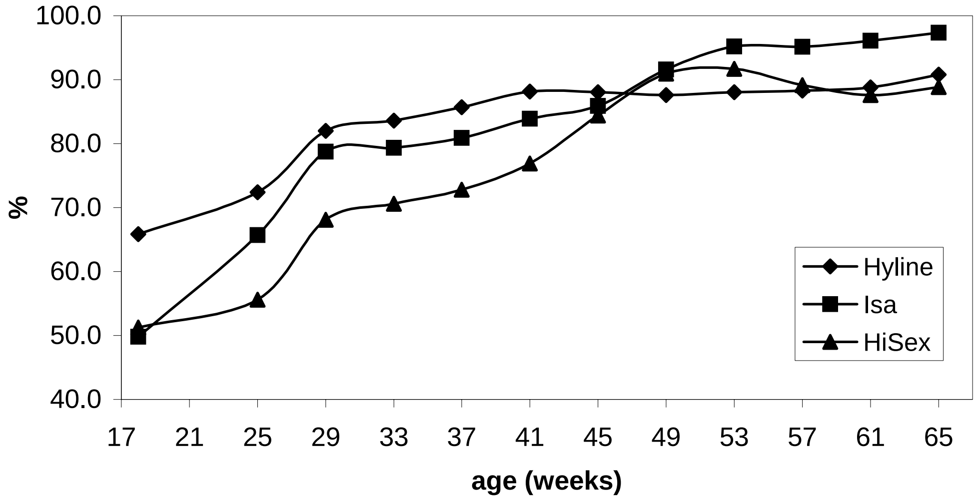

Figure 31. Effect of strain of percentage of eggs laid in nest boxes in barn layer system.

Birds were scored for production and performance factors (egg weight, laying percent, mortalities, percentage of blood stained eggs, feed conversion ratio, bird weight and total feather score) on a 3 point scale with 1 = best result for that factor (heaviest eggs, lowest mortalities etc) and 3 = worst result for that factor (lightest eggs, highest mortalities etc). In the barn system Isa had the lowest score therefore was best suited to the system (table 7).

Table 7. Effect of strain on performance score in a barn layer system (3 point scale with 1 = best result for that factor (heaviest eggs, lowest mortalities etc) = worst result for that factor (lightest eggs, highest mortalities etc).

Barn			
Factor	**Hyline**	**Isa**	**HiSex**
Egg weight (g)	2.5	1	2.5
Lay (%)	1.5	1.5	3
Mortalities (%)	1	2.5	2.5
Blood stained eggs (%)	2	1	3
Feed conversion ratio	2	1	3
Bird weight (g)	1	2	3
Total feather score	2	1	3
Total	**12**	**10**	**20**

4.2 Strain between system

4.2.1 Hyline

Free-range had the heaviest egg weight throughout the trial (except week 53) peaking at 49 weeks with 67.6 grams (figure 32). Free-range egg weight was greater than 65 grams from 45 weeks onwards. The weight of barn eggs peaked at 53 weeks with 67.9 grams, with eggs weighing more than 65 grams from 45 weeks. Cage egg weight peaked in week 57 with 66.6 grams. This was the only time when cage eggs were heavier than 65 grams.

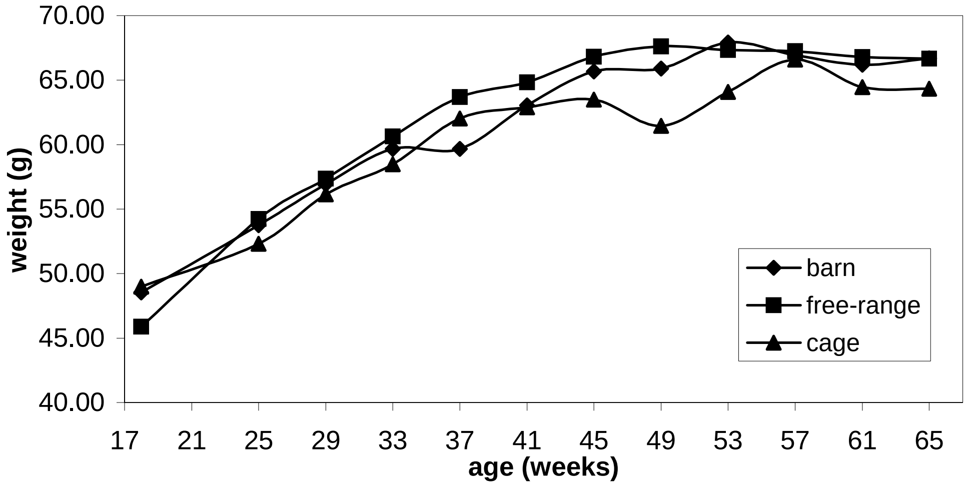

Figure 32. Effect of system on egg weight of Hyline strain.

From week 29, Hyline in the three systems had a laying percentage of, or more than 70%. Cage peaked at or greater than 87% (41 and 57 weeks), barn at 84.2% (41 weeks) and free-range, 82.8% (45 weeks). From week 53, cage had the highest laying percentage followed by barn and then free-range (figure 33).

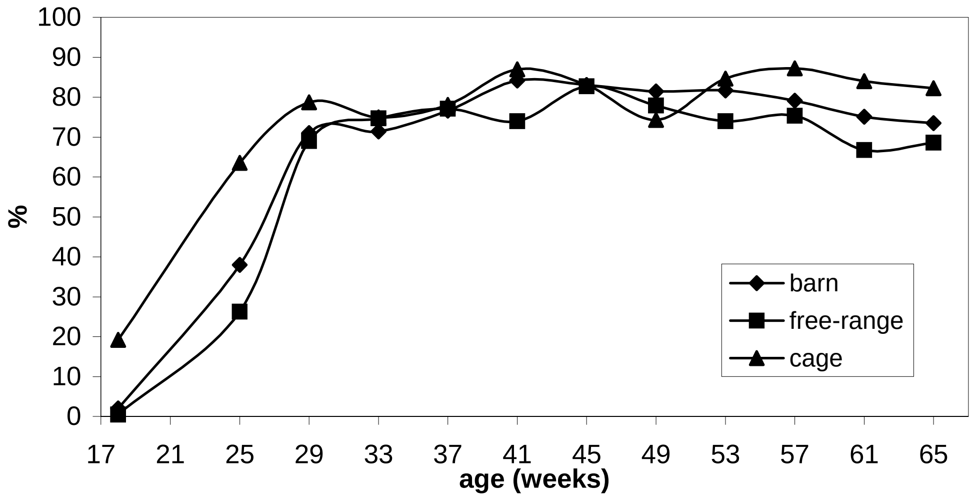

Figure 33. Effect of system on laying percentage of Hyline strain.

Cage had the least blood stained eggs of all the systems during the trial. In the barn, blood stained eggs increased gradually from 18 weeks and then dramatically (2.9% to 5.1%) between 41 and 45 weeks. They increased again to 6.1% during the following month and then started to decline finishing on 4.4%. Free-range were similar to cage until week 41 when the percentage of blood stained eggs produced in the free-range increased. By 49 weeks the percentage of blood stained eggs had increased to 6.2% (figure 34).

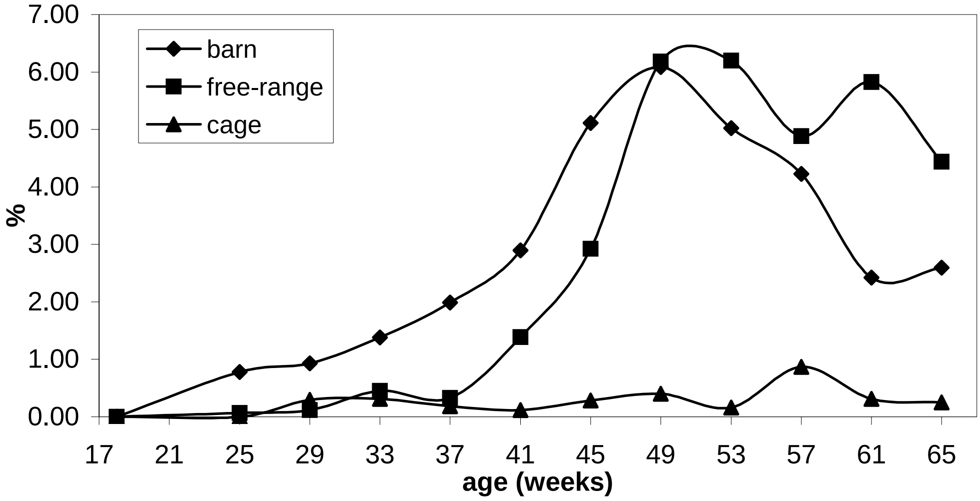

Figure 34. Effect of system on percentage of blood stained eggs of Hyline strain.

Cage had the lowest feed conversion ratio of the three systems throughout the trial (figure 35). At 65 weeks, free-range had the highest at 3.1, followed by barn (2.76) and cage (2.12). Cage bird weight gradually increased during the trial to reach 2133.5 grams by 65 weeks. Barn and free-range bird weight increased at 45 weeks and then decreased at 57 weeks. Barn bird weight decreased again to be 2045.7 grams at 65 weeks. Free-range bird weight increased from 57 to 65 weeks finishing on 2135.9 grams, the heaviest of the three systems (figure 36).

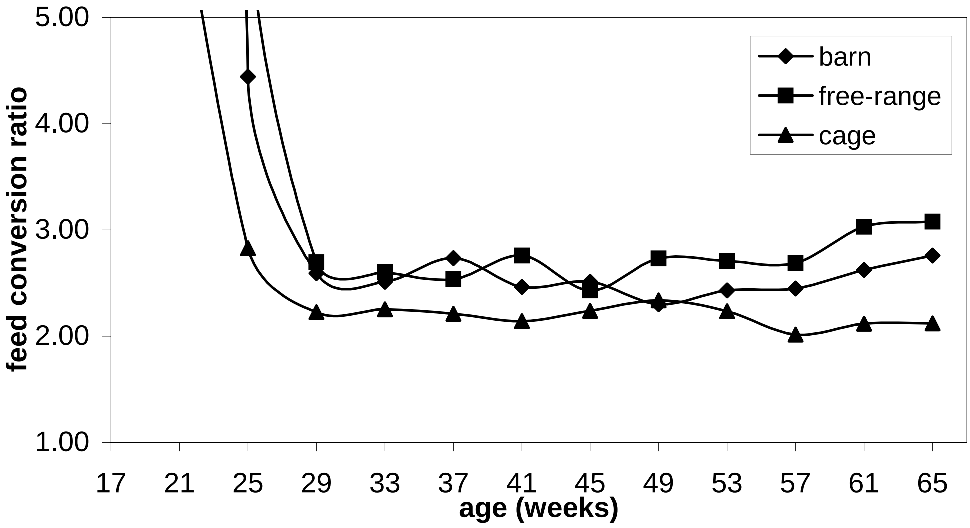

Figure 35. Effect of system on feed conversion ratio of Hyline strain.

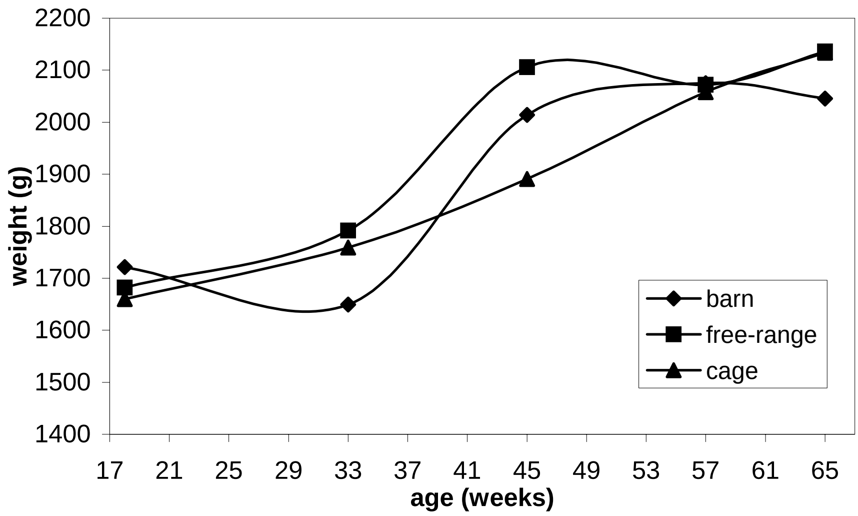

Figure 36. Effect of system on bird weight of Hyline strain.

Free-range had the highest percentage mortality during the trial, reaching 12.2% at week 49 and being greater than 5% from week 37 to 53 (figure 37). From week 41 to week 49, mortality was greater than 10%. Barn peaked at 5.7% at week 33 and then was fairly stable around 2% for the remainder of the trial. Cage was low until week 49 where it dramatically increased from 0% (week 45) to 9.1% and then down to approximately 2% (week 53).

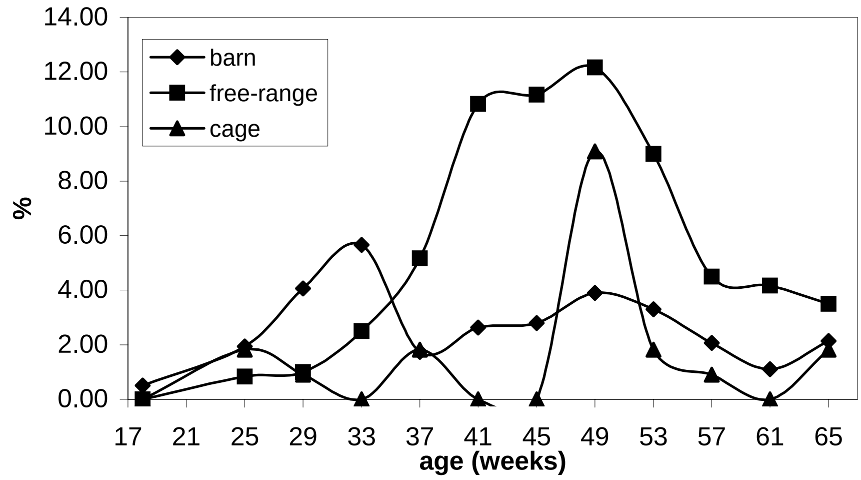

Figure 37. Effect of system on mortality of Hyline strain.

The three strains had similar total body feather scores until 45 weeks when barn dropped below cage and free-range (figure 38). Free-range finished with a total body feather score of 2.73, followed closely by cage on 2.61, with barn finishing on 2.13.

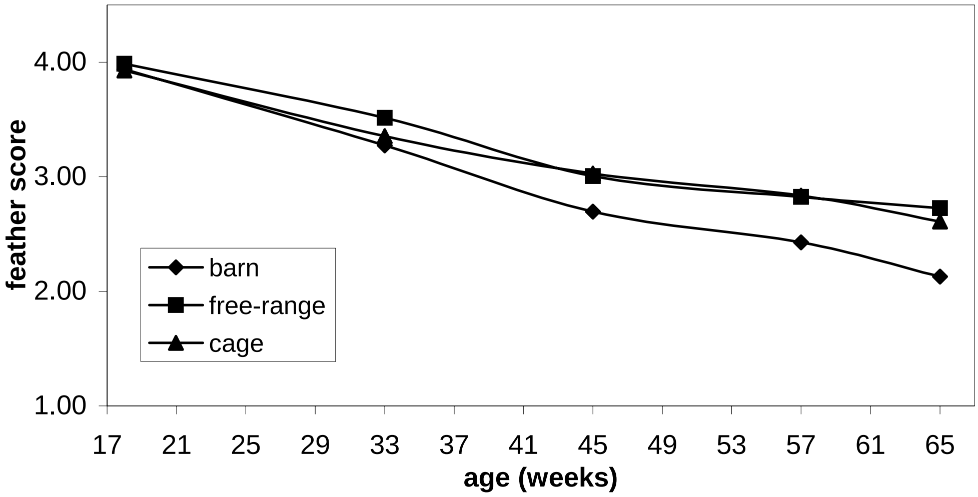

Figure 38. Effect of system on total feather score of Hyline strain.

Free-range had the highest neck feather score throughout the trial finishing on a score of 3.21. Cage and barn were alternatively higher or lower than each other during the trial with cage finishing with a score of 2.32 and barn, 1.95 (figure 39).

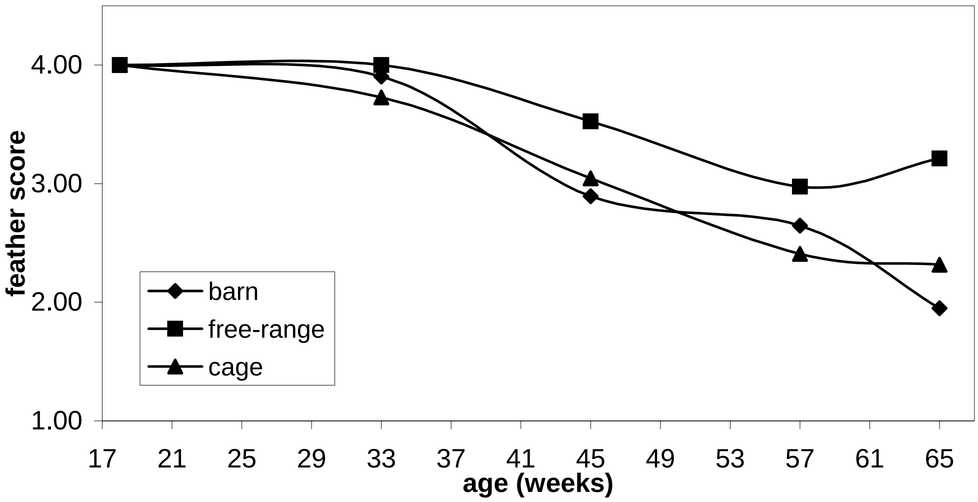

Figure 39. Effect of system on neck feather score of Hyline strain.

Cage had the highest back feather score for the duration of the trial. Barn and free-range back feather score decreased together until 57 weeks when free-range back feather score stabilised (figure 40). From week 57 to week 65, barn back feather score increased from 1.38 to 1.76, with free-range finishing on 1.82 and cage on 2.82. Free-range breast feather score was highest throughout the trial finishing on 2.78. Cage and barn breast feather scores declined together until 57 weeks when cage scores stabilised and finished on a score of 2.50 (figure 41). Barn continued to decline reaching a feather score of 1.90 at 65 weeks. Barn and free-range wing feather scores were similar until 65 weeks when barn scores decreased dramatically (figure 42). Cage wing feather score was the lowest throughout the trial until week 65 when barn was the lowest. Free-range finished with the wing feather score of 3.74, followed by cage with 2.95, and barn, 2.32.

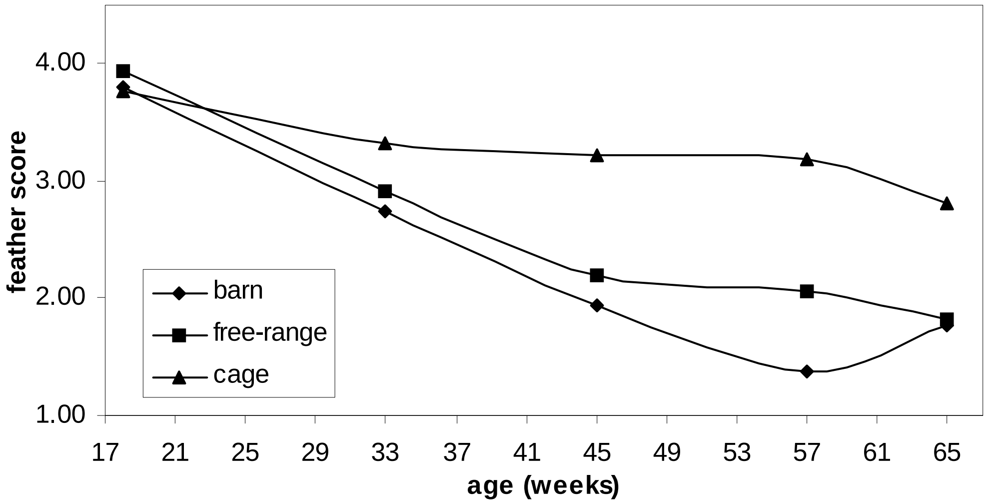

Figure 40. Effect of system on back feather score of Hyline strain.

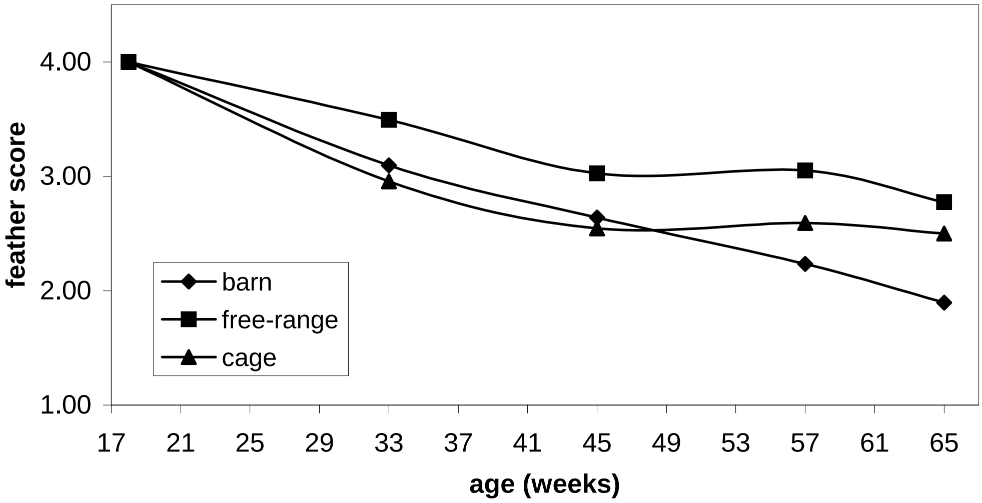

Figure 41. Effect of system on breast feather score of Hyline strain.

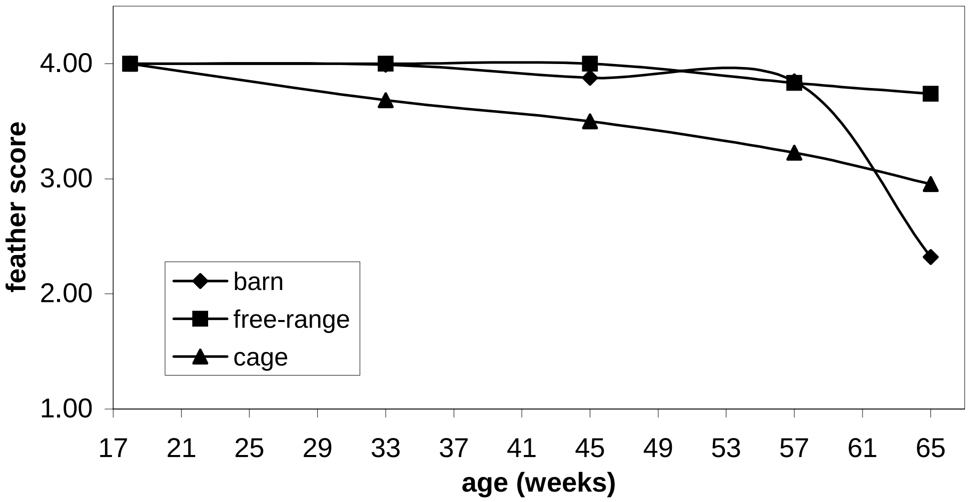

Figure 42. Effect of system on wing feather score of Hyline strain.

All three systems tail feather score decreased throughout the trial, with the exception of barn tail feather score, which increased from week 57 to week 65 finishing with a score of 2.71 (figure 43). Cage finished with a score of 2.45 and free-range 2.08.

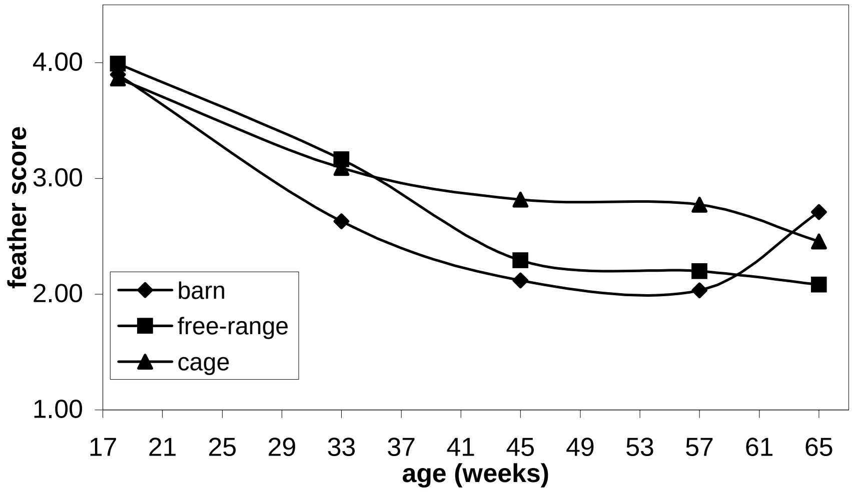

Figure 43. Effect of system on tail feather score of Hyline strain.

Foot score (combined toe pad hyperkerotosis, bumble foot and claw length) did not differ for the three systems for the duration of the trial. The scores were never below 3.91 for any system during the trial (figure 44).

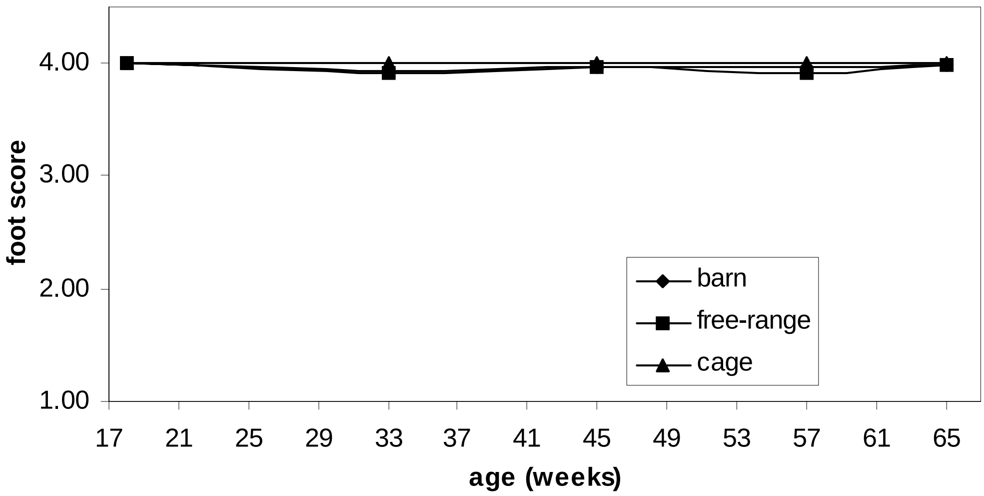

Figure 44. Effect of system on total foot score of Hyline strain.

4.2.2 Isa

Egg weight was similar for the three systems until week 45 when cage dropped below barn and free-range. Free-range and barn eggs had similar weights throughout the trial finishing on 69.7 grams and 68.8 grams respectively. Cage egg weight finished on 65.6 grams (figure 45). Cage birds had the highest laying percentage throughout the trial except for week 49. Their laying percentage peaked at 41 weeks at 88.9%. Barn and free-range peaked at 49 weeks with 83.14% and 83.91% respectively. Cage finished on 81.3%, followed by free-range on 76.68% and barn on 74.34% (figure 46).

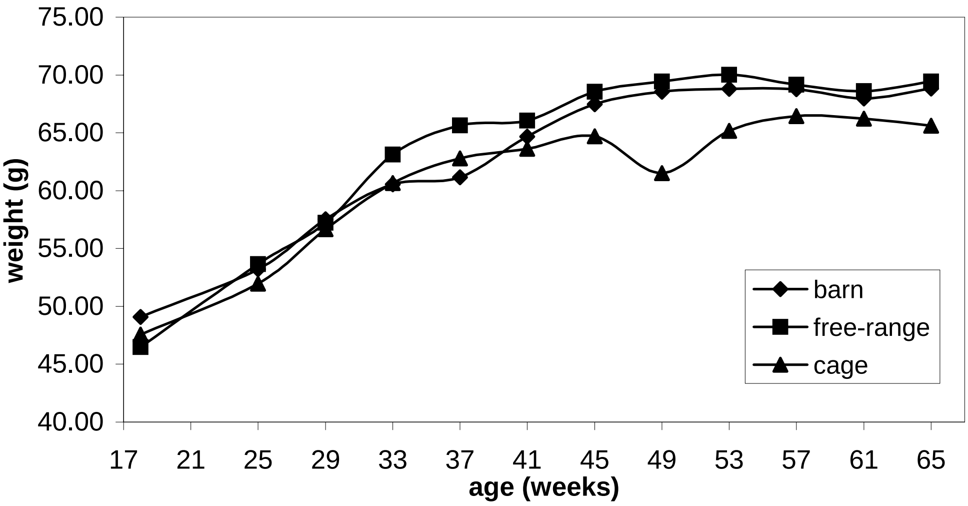

Figure 45. Effect of system on egg weight of Isa strain.

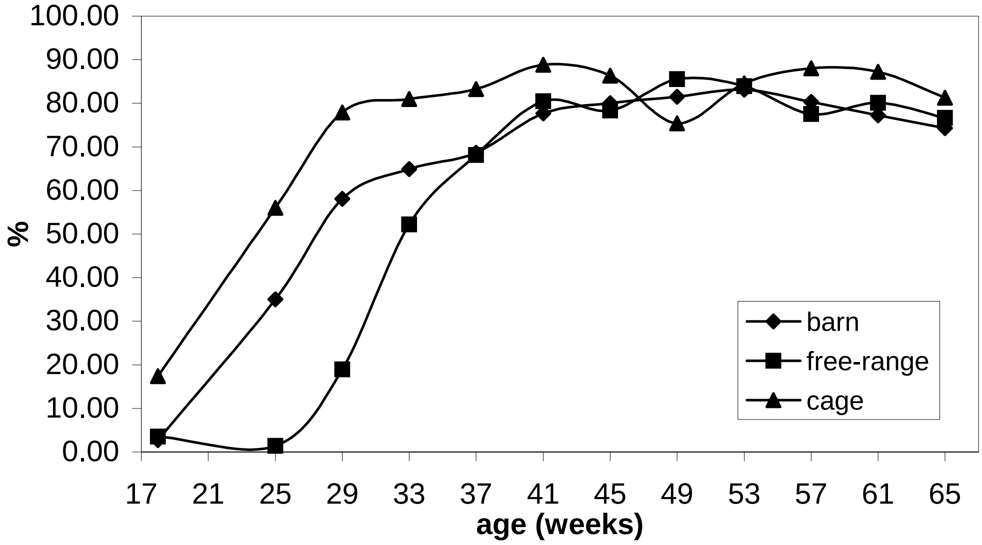

Figure 46. Effect of system on laying percentage of Isa strain.

All systems had similar percentage of blood stained eggs until week 41 when barn and free-range started to increase. From week 45 to 57, free-range blood stained eggs increased from 2.1% to 6.4% to 8.3% to 9.2% decreasing to 7.0% by 65 weeks. Barn blood stained eggs peaked at 5.2% at week 61 and cage at 2.5% at week 53 (figure 47).

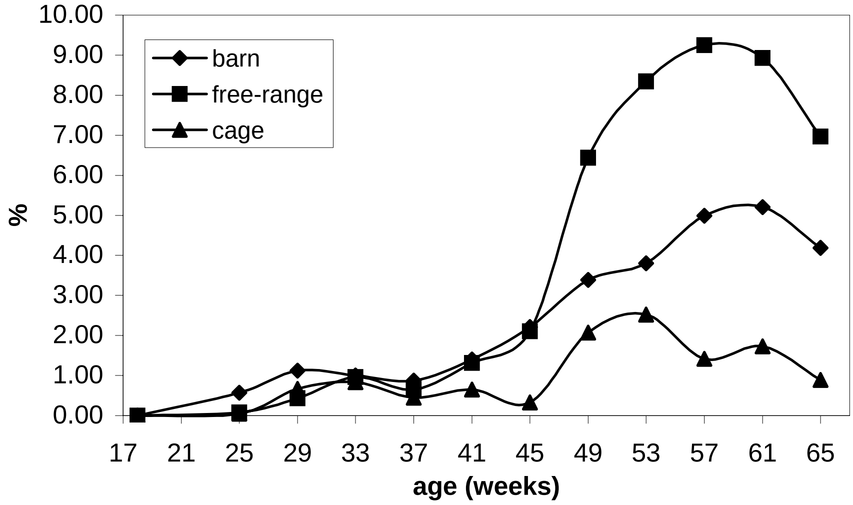

Figure 47. Effect of system on blood stained eggs of Isa strain.

Cage had the lowest feed conversion ratio throughout the trial finishing on 2.05. Barn and free-range had similar feed conversion ratios finishing on 2.56 and 2.53 respectively (figure 48).

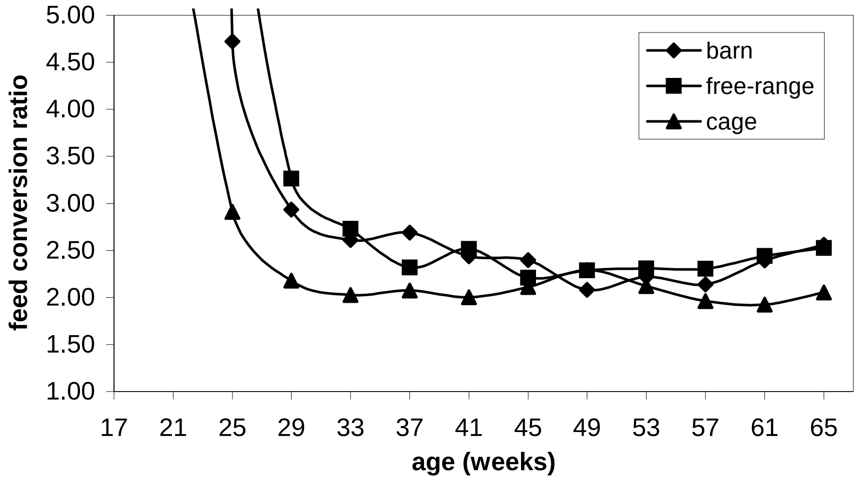

Figure 48. Effect of system on feed conversion ratio of Isa strain.

At 18 weeks cage had the highest bird weight, however by 33 weeks free-range were the heaviest. From 45 weeks barn and cage birds had very similar bird weights, peaking at 57 weeks (2003.0 grams and 1997.5 grams, respectively) and finishing on 1969.0 grams and 1967.4 grams, respectively. Free-range weight peaked at the end of the trial at 2079.2 grams (figure 49).

Cage had the lowest mortality throughout the trial peaking with 4.5% at 49 weeks, with zero mortalities for 7 months of trial. Barn had the highest mortality from week 18 to week 37, with free-range increasing dramatically in week 41 to have the highest mortality until week 61. Barn mortality peaked at weeks 33 and 49 with 6.1%. Free-range peaked at week 49 with 14.8% and spent 5 months with mortalities greater than 6% (figure 50).

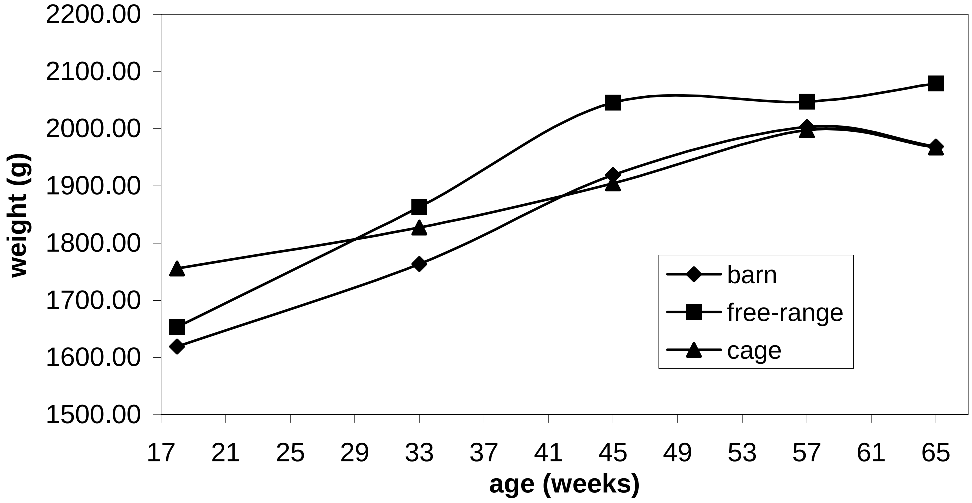

Figure 49. Effect of system on bird weight of Isa strain.

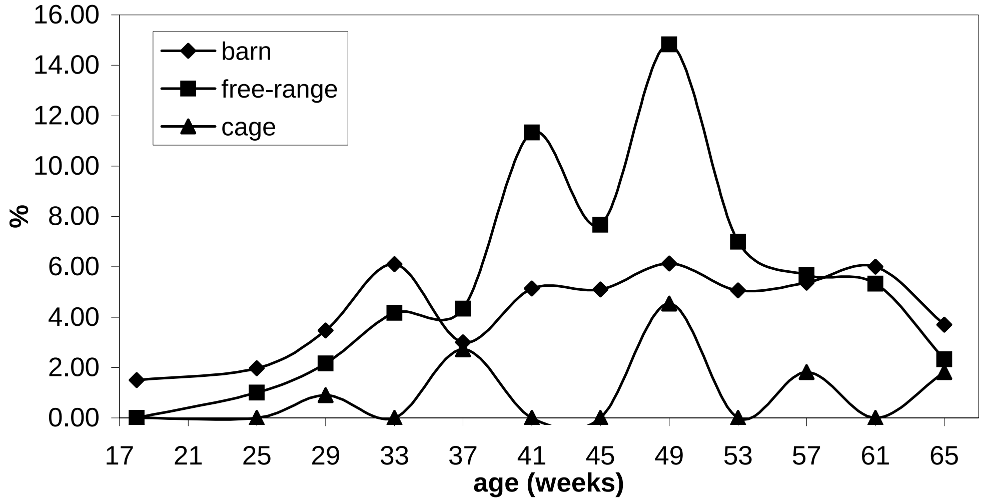

Figure 50. Effect of system on mortality of Isa strain.

Total feather score was very similar for all the systems throughout the trial, with free-range finishing on 2.88, barn on 2.84 and cage, 2.72 (figure 51). From week 45, barn neck feather score fell below the other systems, however cage neck feather score then decreased dramatically from week 57 falling below the barn and free-range systems (figure 52). Free-range finished with the highest neck feather score (3.47), followed by barn (2.97) and cage (2.59). Cage had the highest back feather score throughout the trial finishing on a score of 2.68. Barn and free-range were very similar at week 57, however at week 65 barn had increased to 2.54 and free-range decreased to 1.86 (figure 53).

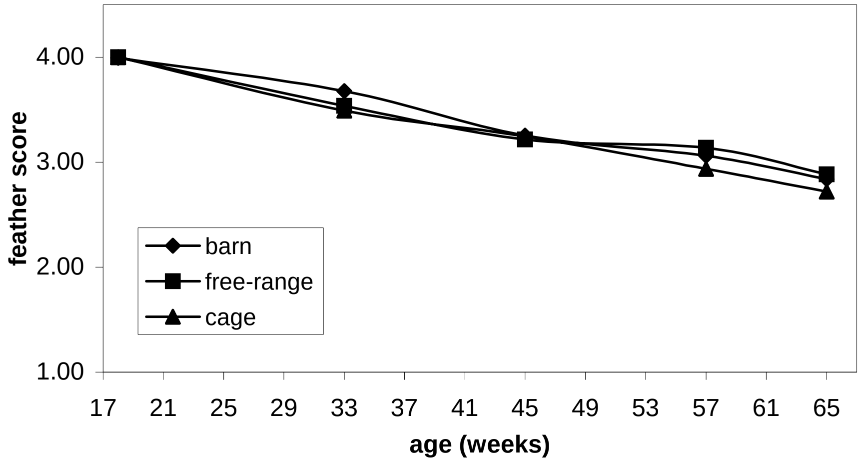

Figure 51. Effect of system on total bird feather score of Isa strain.

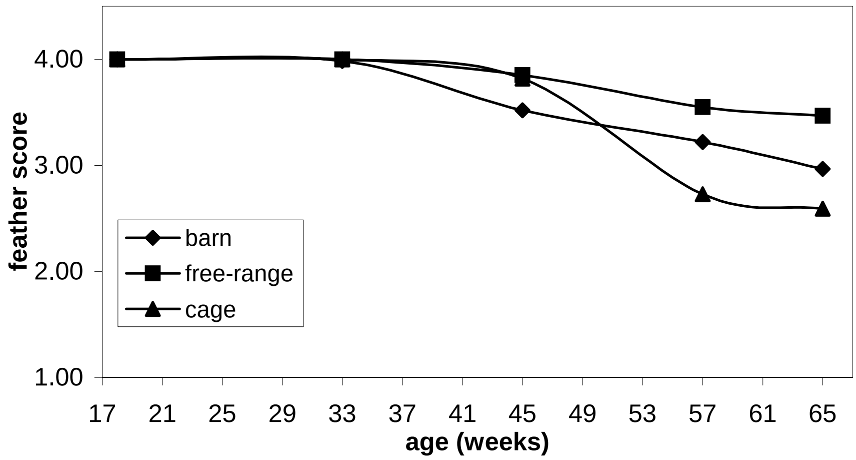

Figure 52. Effect of system on neck feather score of Isa strain.

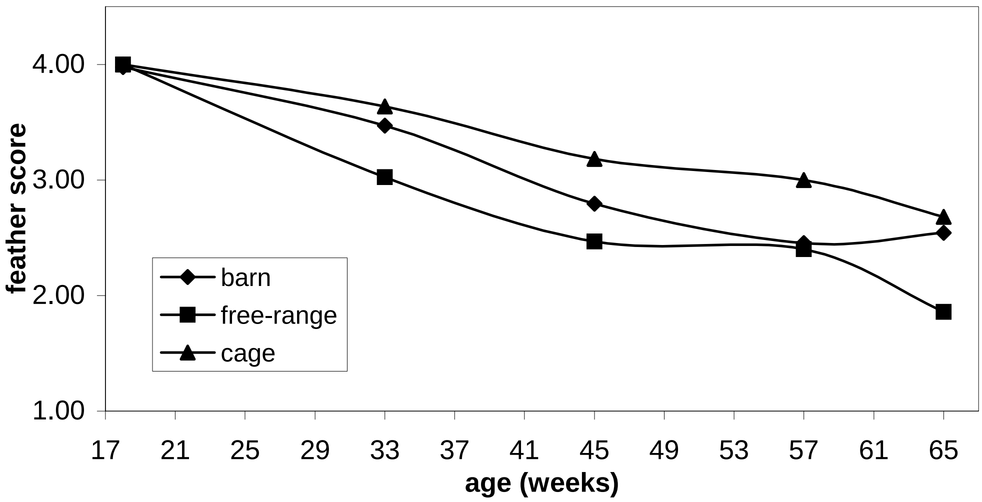

Figure 53. Effect of system on back feather score of Isa strain.

Cage breast feather score decreased from week 18 to week 33, however it was then relatively stable until the end of the trial finishing on 2.77. Barn and free-range were very similar until 57 weeks when free-range breast feather score increased. Free-range had a breast feather score of 2.98 at 65 weeks and barn 2.77 (figure 54).

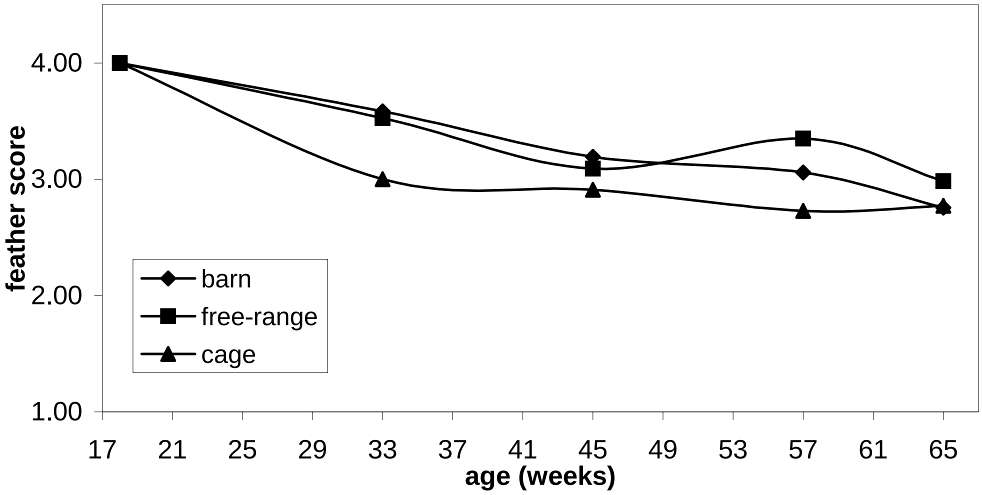

Figure 54. Effect of system on breast feather score of Isa strain.

The cage system had the lowest wing feather score throughout the trial, with barn and free-range very similar until week 65. At week 65, free-range had a wing feather score of 3.85 followed by barn and cage on the same score (2.91) (figure 55). Tail feather score was similar for all systems until week 57 when cage had a higher score and week 65 when barn tail feather score increased (figure 56). Barn finished with the highest tail feather score (3.02), followed by cage (2.64) and free-range (2.26). Foot score (combined toe pad hyperkerotosis, bumble foot and claw length) did not differ for the three systems for the duration of the trial. The scores were never below 3.96 for any system during the trial (figure 57).

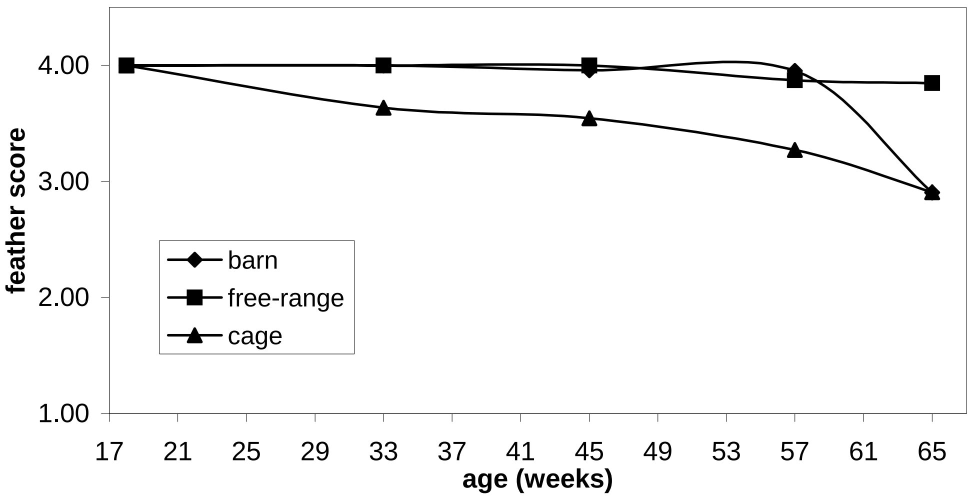

Figure 55. Effect of system on wing feather score of Isa strain.

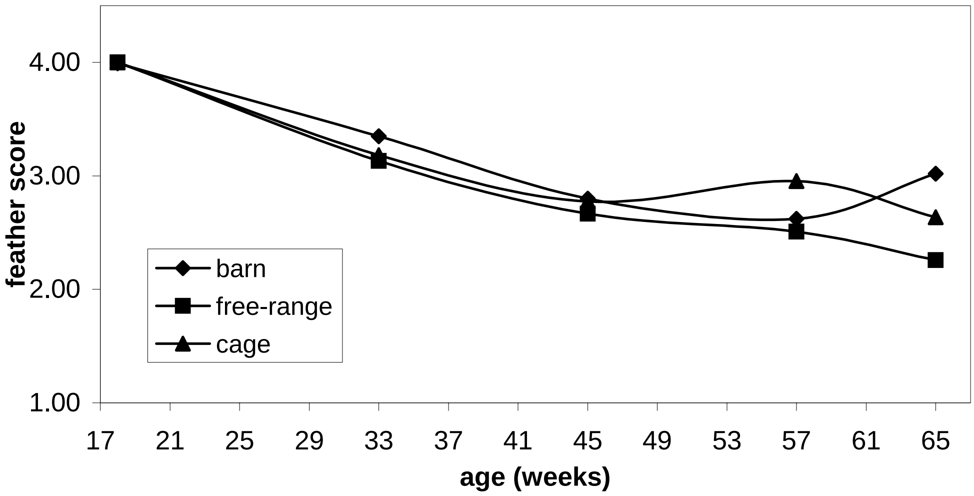

Figure 56. Effect of system on tail feather score of Isa strain.

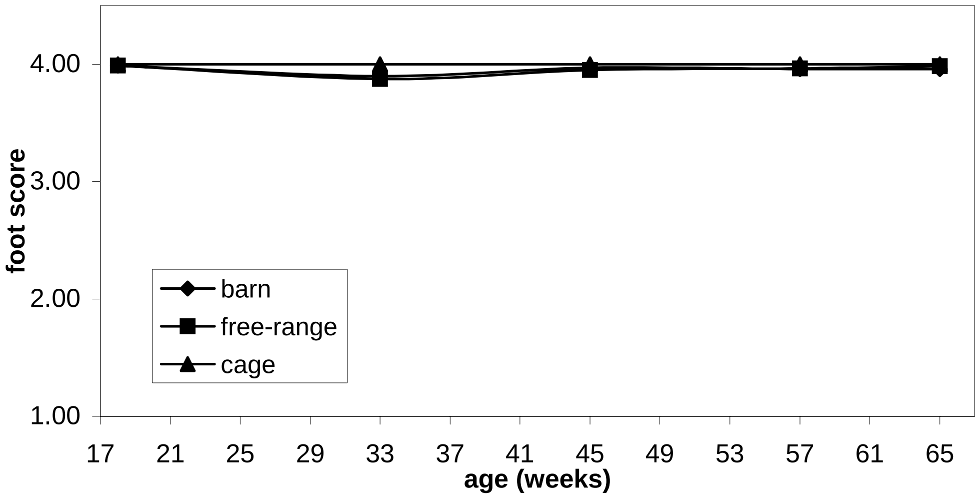

Figure 57. Effect of system on total foot score of Isa strain.

4.2.3 HiSex

Free-range and barn had similar egg weights throughout the trial with cage egg weight lower from week 41. Both barn and free-range egg weight peaked at 66.6 grams (barn - week 65 and free-range - week 53). Cage egg weight peaked at 64.4 grams (week 57) and finished on 64.1 grams (figure 58).

Cage had the highest laying percentage during the trial except for week 49 peaking at 87.7% (week 41) and finishing on 84.7%. Free-range peaked at week 49 on 85.5% and finished on 70.0%, with barn peaking on 78.0% (week 41) and finishing on 68.3% (figure 59).

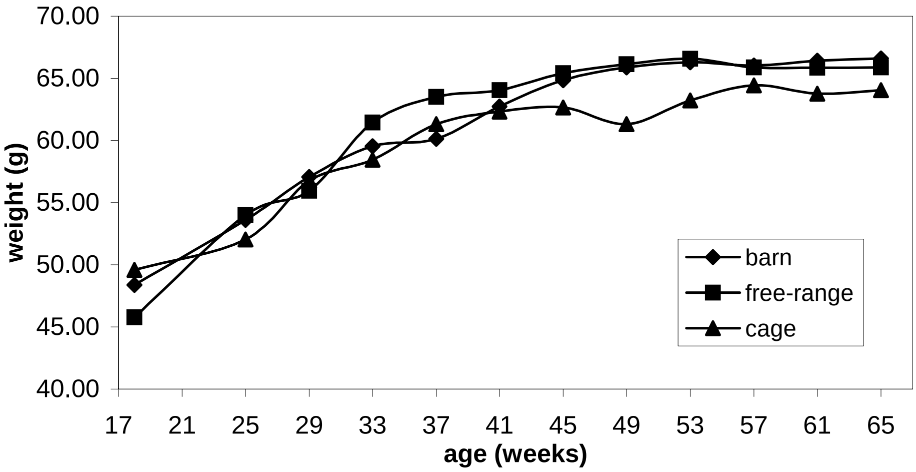

Figure 58. Effect of system on egg weight of HiSex strain.

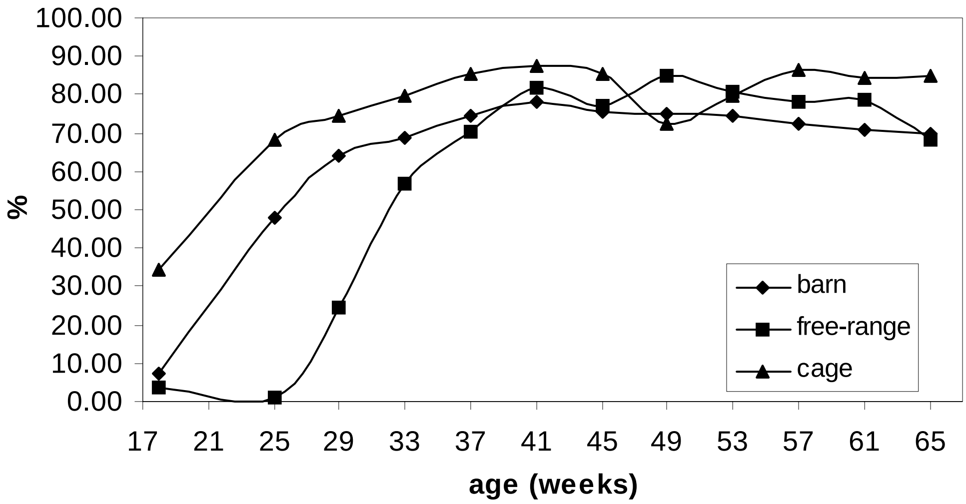

Figure 59. Effect of system on laying percentage of HiSex strain.

Free-range and barn blood stained egg percentage followed the same general trend during the trial, with barn peaking on 4.9% (week 45) and free-range 4.7% (week 49). Cage blood stained eggs did not get higher than 1% throughout the trial (figure 60). Cage had the lowest feed conversion ratio throughout the trial finishing on 1.98 with all three systems similar from weeks 45 to 53. Barn feed conversion ratio at the end of the trial was 3.08 and free-range, 2.80 (figure 61). Cage bird weight was the highest from 18 weeks to 33 weeks, with free-range the highest from 45 weeks finishing on 1991.5 grams. Cage bird weight was 1919.1 grams at 65 weeks and barn, 1963.4 grams (figure 62).

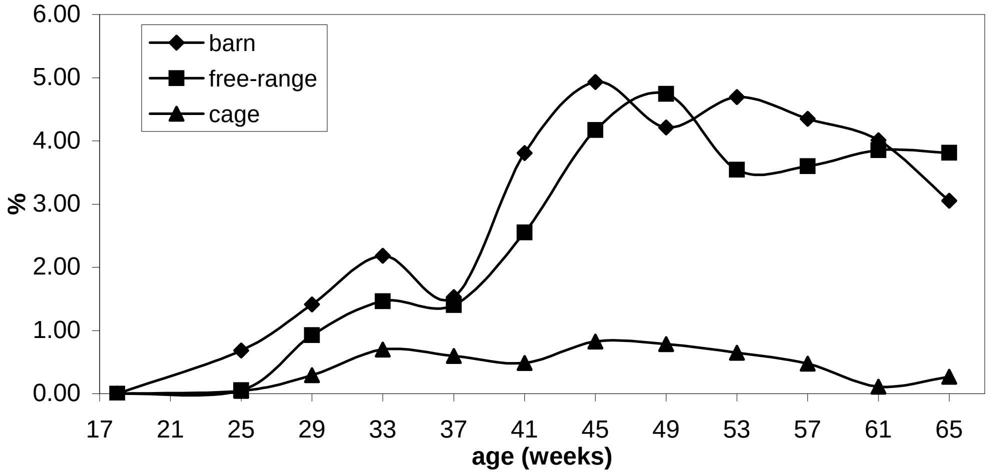

Figure 60. Effect of system on blood stained eggs of HiSex strain.

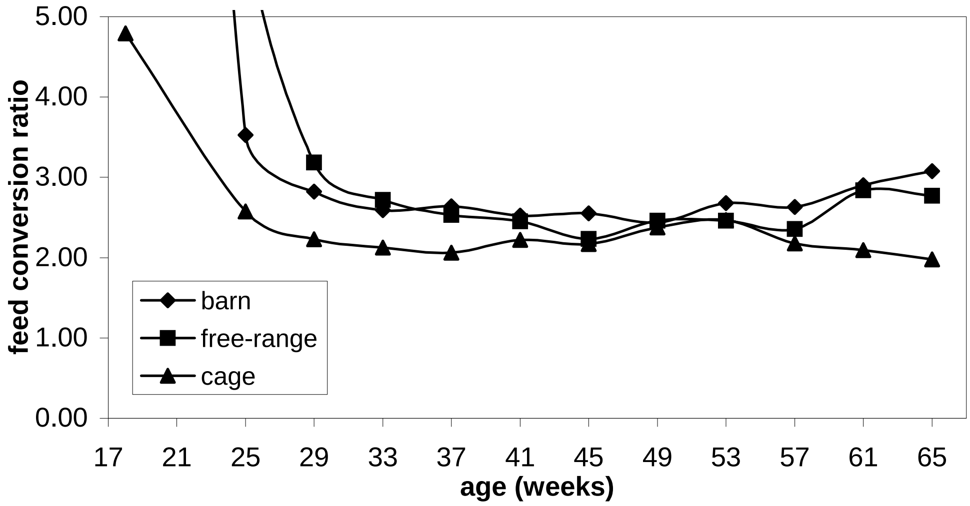

Figure 61. Effect of system on feed conversion ratio of HiSex strain.

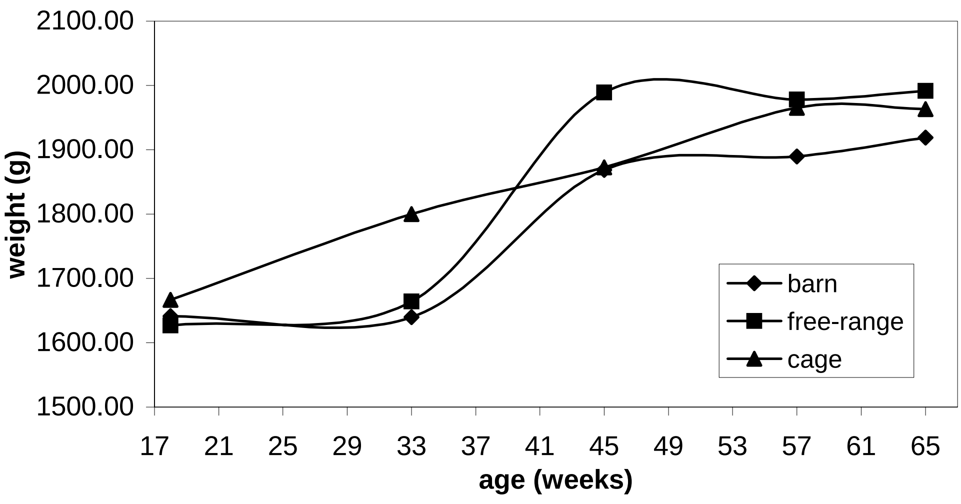

Figure 62. Effect of system on bird weight of HiSex strain.

Barn mortality peaked the earliest of the three systems, with 8.7% at 29 weeks. At 33 weeks, free-range mortality peaked at 13.2% and remained above 10% until week 45. Cage mortality peaked at 16.4% at 49 weeks, with a lower peak of 4.5% at week 37, however for 7 months of the trial cage mortality was zero (figure 63).

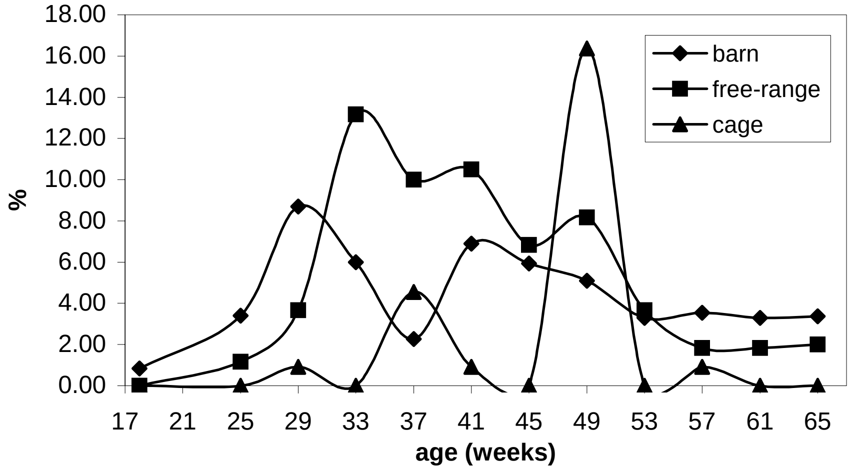

Figure 63.Effect of system on mortality (%) of HiSex strain.

Barn had the lowest total bird feather score throughout the trial finishing on 1.89, with cage and free-range having similar scores until 65 weeks. Free-range finished with a total bird feather score of 2.5, with cage on 2.15 (figure 64).

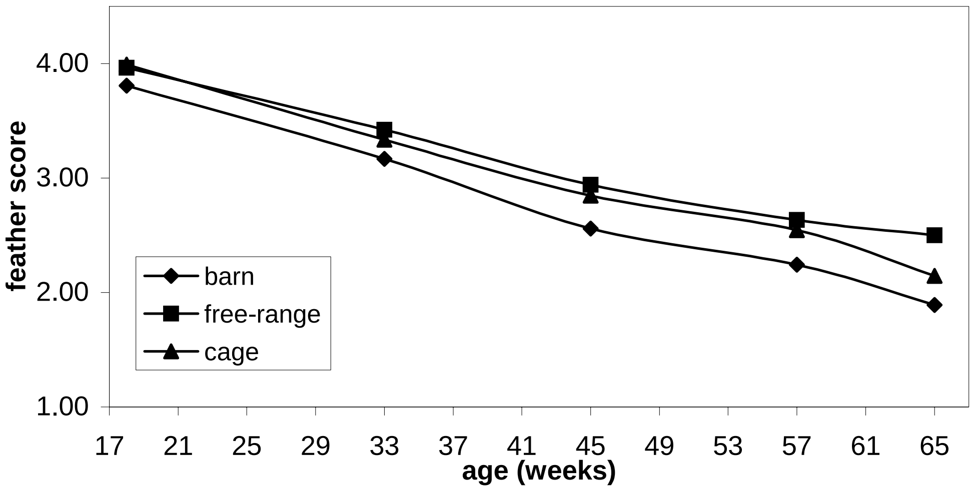

Figure 64. Effect of system on total bird feather score of HiSex strain.

Cage had the lowest neck feather score throughout the trial except for week 65 where barn had the lowest score however the scores were very similar (1.39 - barn and 1.55 - cage). Free-range had the highest neck feather scores during the trial finishing on a score of 3.34 (figure 65). Barn and free-range back feather scores were similar during the trial with free-range having a slightly higher score until 65 weeks when barn score increased from 1.37 to 1.85 and free-range decreased from 1.78 to 1.40. Cage had the highest throughout the trial finishing on a back feather score of 2.64 (figure 66). Cage and free-range had a similar breast feather scores for the duration of the trial with free-range being slightly higher. Free-range breast feather score finished on 2.48, followed by cage on 2.14 and barn on 1.63 (figure 67).

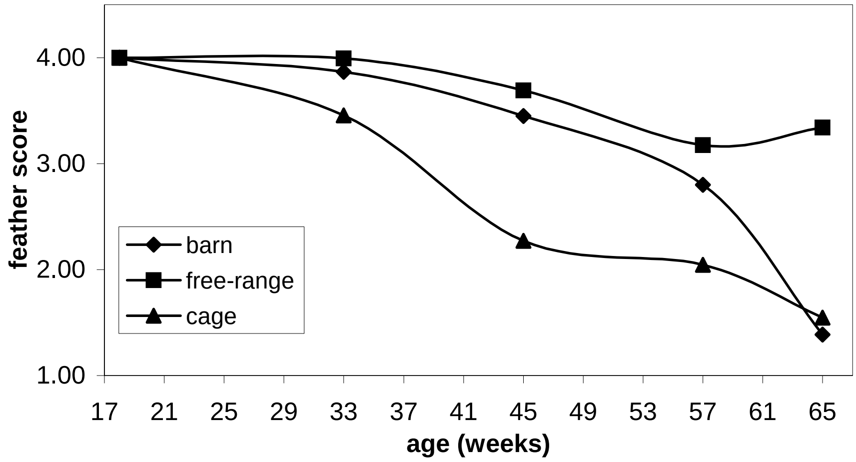

Figure 65. Effect of system on neck feather score of HiSex strain.

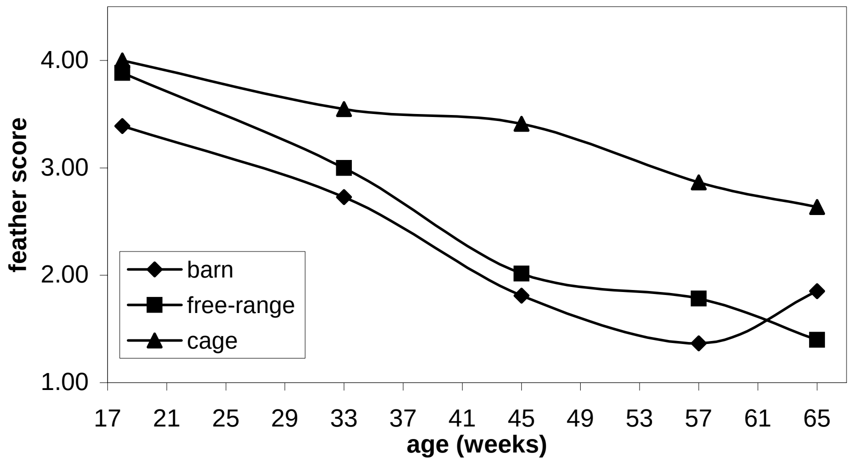

Figure 66. Effect of system on back feather score of HiSex strain.

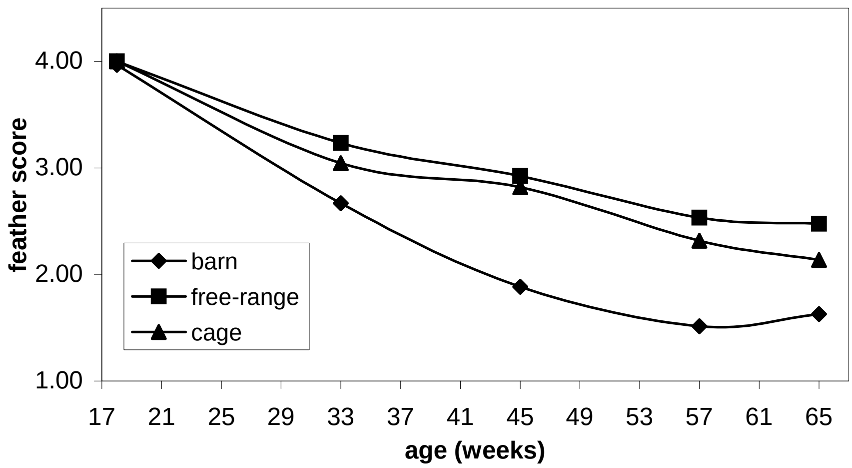

Figure 67. Effect of system on breast feather score of HiSex strain.

Barn and free-range had similar wing feather scores until week 65 when barn decreased from 3.58 to 2.11. Free-range finished on 3.53 with cage having the lowest wing feather score during the trial and finishing on 2.68 (figure 68).

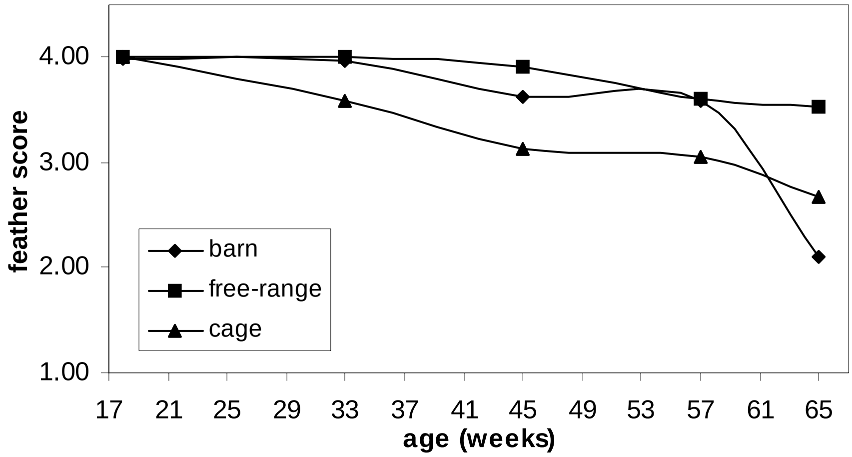

Figure 68. Effect of system on wing feather score of HiSex birds.

Cage had the highest tail feather score during the trial until 65 weeks when barn had the highest score (figure 69). Barn finished with a tail feather score of 2.49, followed by free-range (1.75) and cage (1.73).

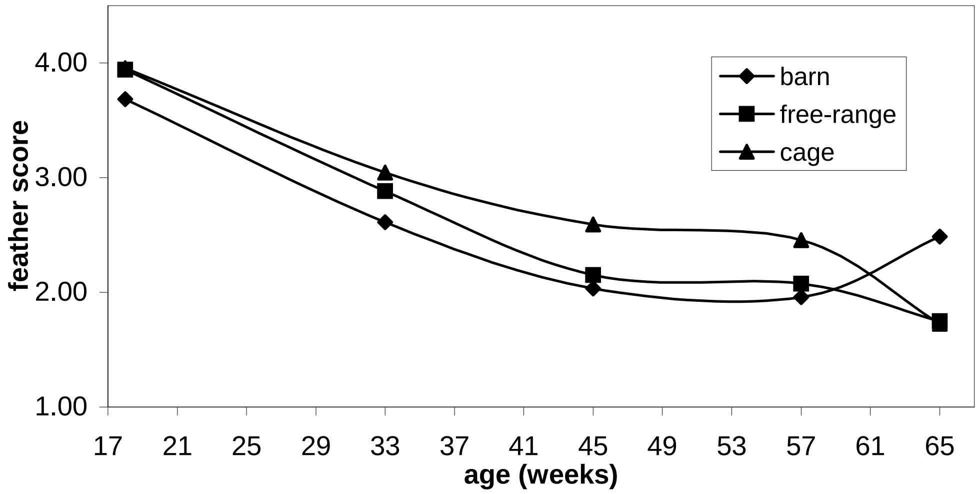

Figure 69. Effect of system on tail feather score of HiSex birds.

Foot score (combined toe pad hyperkerotosis, bumble foot and claw length) did not differ for the three systems for the duration of the trial. The scores were never below 3.93 for any system during the trial (figure 70).

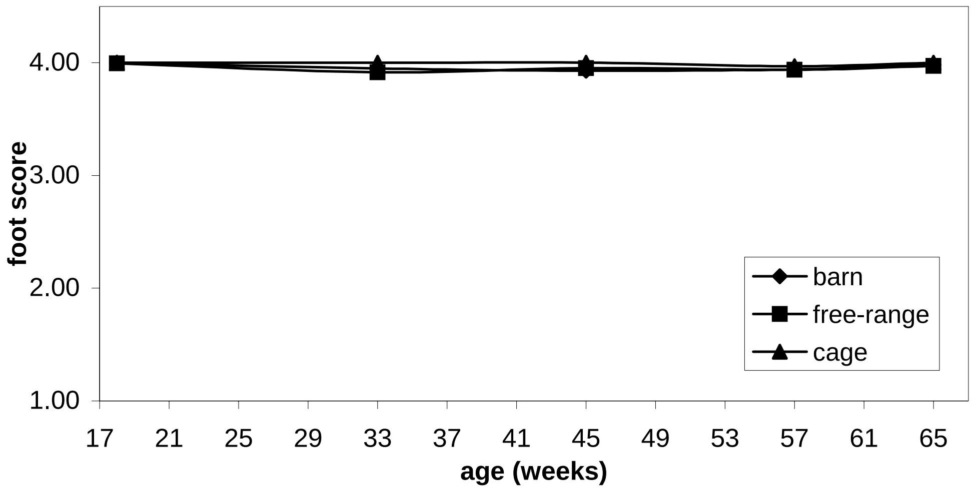

Figure 70. Effect of system on total foot score of HiSex strain.

4.3 System

Free-range had the heaviest eggs from 33 weeks until 65 weeks, when barn eggs were slightly heavier (67.3 grams and 67.4 grams, respectively). Barn (67.7 grams) and free-range (68.0) eggs both peaked at 53 weeks with cage eggs peaking at 57 weeks (65.8). Cage had the lightest eggs from week 41 (figure 71).

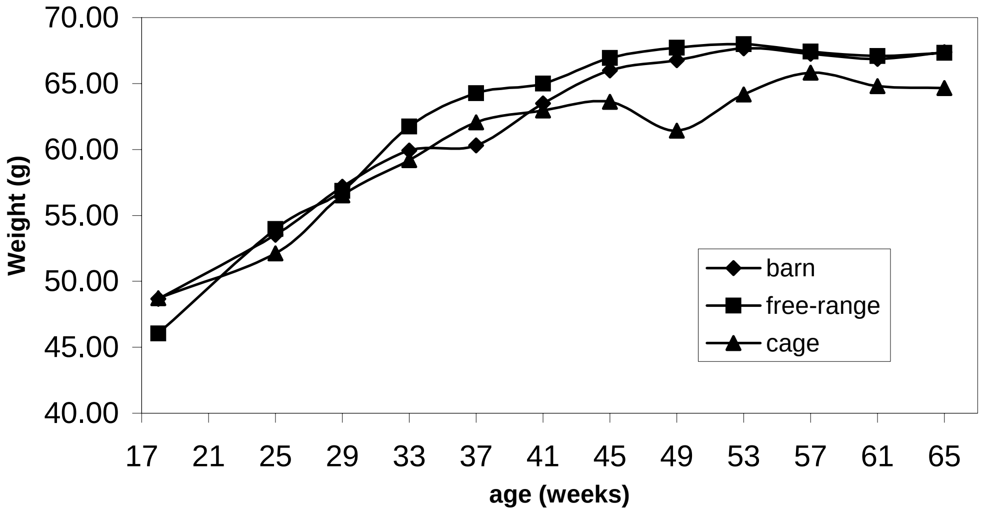

Figure 71. Effect of system on egg weight.

Cage had the highest laying percentage during the trial (except week 49), peaking at week 57 with 87.2% and finishing on 82.8%. Barn and free-range had similar laying percentages finishing on 72.6% and 70.6%, respectively. Barn peaked on 80.0% at week 45 while free-range peaked a month later with 84.5% (figure 72). Cage had the lowest blood stained eggs throughout the trial peaking on 1.1% for weeks 49-53. From week 49, free-range had the highest percentage of blood stained eggs with greater than 5% to the end of the trial. Barn had greater than 4% blood stained eggs from week 45 to week 57 (figure 73). System did not have any effect on specific gravity of eggs (table 8). Yolk colour of the three systems was similar with cage yolk colour one point below barn and free-range yolk colour at weeks 35 and 42 (table 8).

Table 8. Effect of system on specific gravity and yolk colour of eggs.

Strain	Specific Gravity			Yolk Colour		
Week	35	42	54	35	42	54
Barn	1.09	1.08	1.09	12.5	12.6	11.1
Free-range	1.09	1.08	1.08	12.3	12.9	11.3
Cage	1.09	1.08	1.08	11.3	11.4	11.2

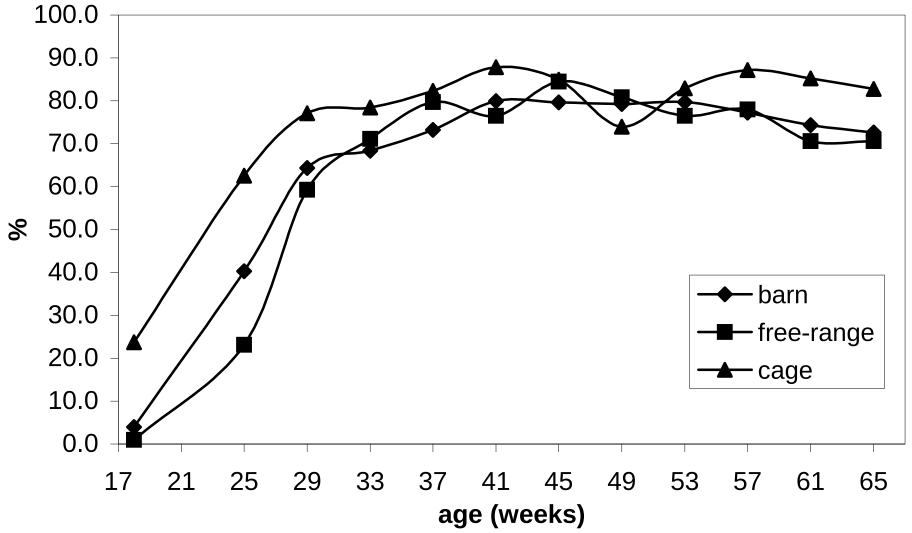

Figure 72. Effect of system on laying percentage.

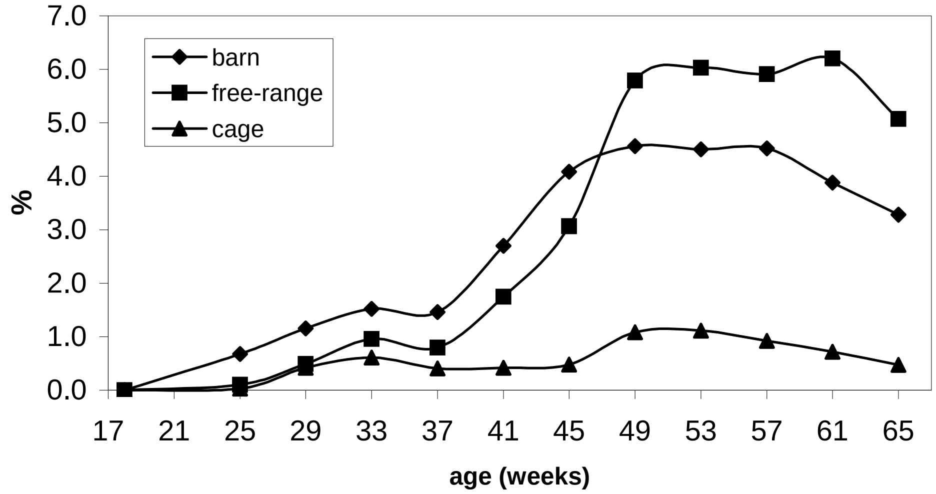

Figure 73. Effect of system on percentage of blood stained eggs.

Barn and free-range had similar feed conversion ratios during the trial, increasing in the final months of the trial to finish on 2.80 and 2.79 respectively. Cage had the lowest feed conversion ratio throughout the trial (except week 49) finishing on 2.05 (figure 74).

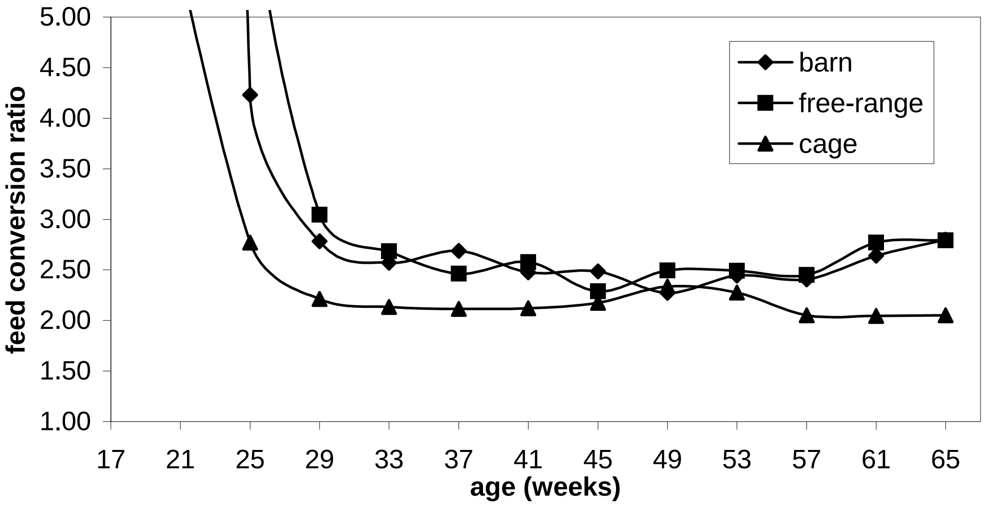

Figure 74. Effect of system on feed conversion ratio.

Free-range had the heaviest bird weights from week 45, with barn the lowest, except for week 45 when barn was slightly heavier than cage. Free-range and cage bird weight peaked at week 65 with 2068.8 grams and 2021.4 grams, respectively. Barn peaked a week earlier with 1989.1 grams (figure 75).

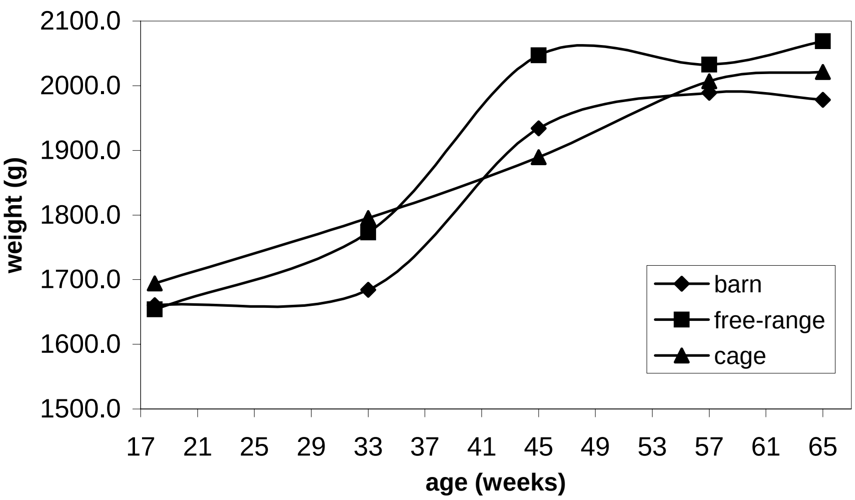

Figure 75. Effect of system on bird weight.

Barn mortality peaked the earliest with 5.9% at week 33, and remained steady at approximately 5.0% for the remainder of the trial. Cage had eight months where mortality was less than 1.0%, however had two peaks, one of 3.0% and one of 10.0% (week 37 and week 49, respectively. Free-range mortality was higher than 6.0% from week 33 to week 53, peaking at 11.7% at week 49 (figure 76).

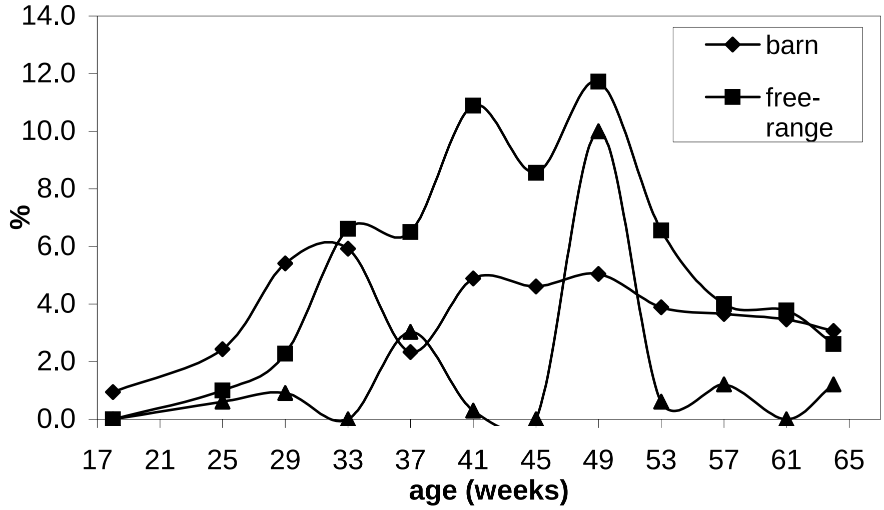

Figure 76. Effect of system on mortality.

Total bird feather score was similar for all three systems during the trial with barn having the lowest score throughout the trial. At week 65, free-range had the highest score with 2.70 followed by cage with 2.50 and barn with 2.29 (figure 77). Free-range had the highest neck feather score throughout the trial finishing with a score of 3.34. Cage had the lowest score until week 65 when barn neck feather score dropped below it. Cage finished with a score of 2.15 and barn 2.10 (figure 78). Cage had the highest back feather score during the trial with barn and free-range having very similar scores. From week 57 to week 65 barn back feather score increased and finished on 2.10, while free-range score continued to decrease and finished on 1.69 (figure 79).

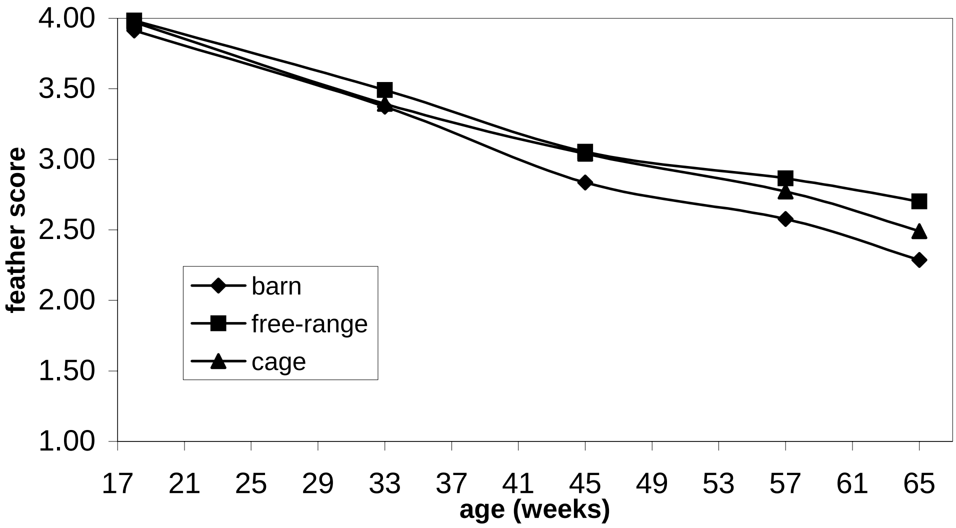

Figure 77. Effect of system on total bird feather score.

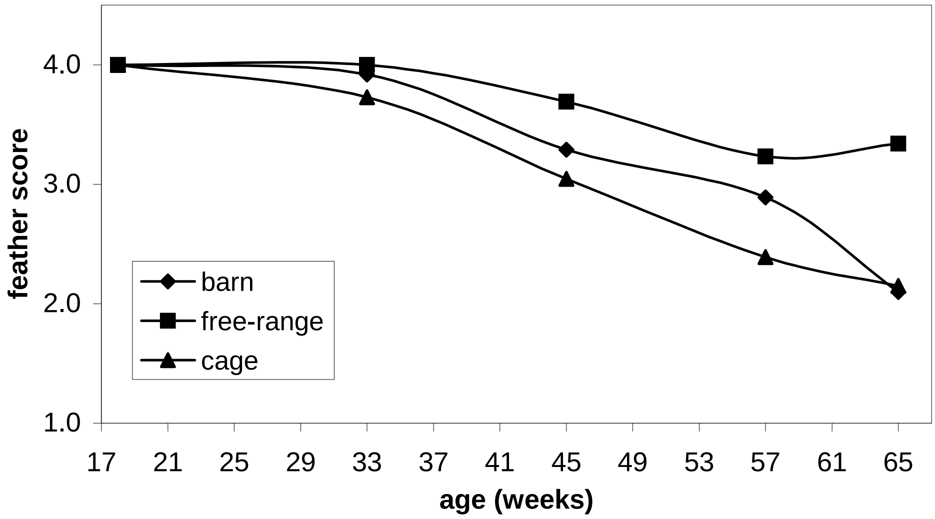

Figure 78. Effect of system on neck feather score**.**

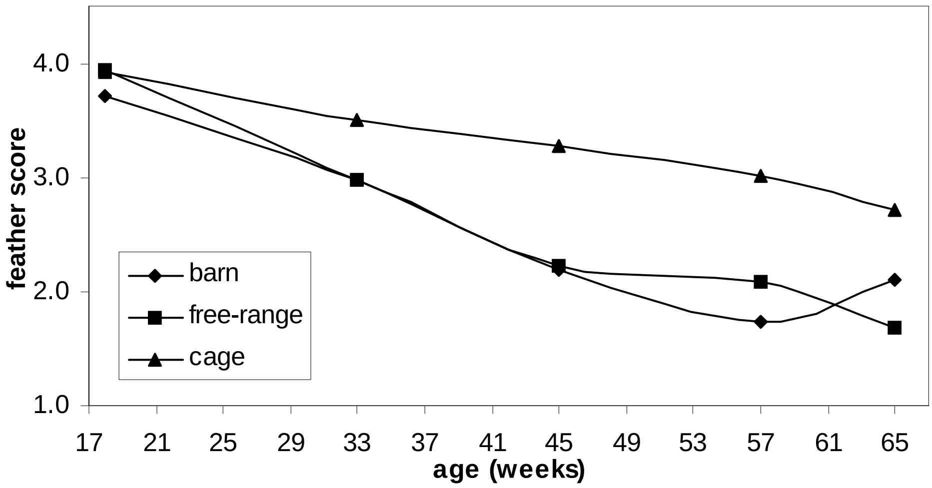

Figure 79. Effect of layer system on back feather score.

Free-range had the highest breast feather score throughout the trial with barn having the lowest from week 45 onwards. Free-range finished with a breast feather score of 2.74, cage, 2.47 and barn, 2.10 (figure 80). Cage had the lowest wing feather score until week 65 when barn wing feather score decreased dramatically. Free-range finished with a wing feather score of 3.71, followed by cage, 2.85 and barn, 2.40 (figure 81).

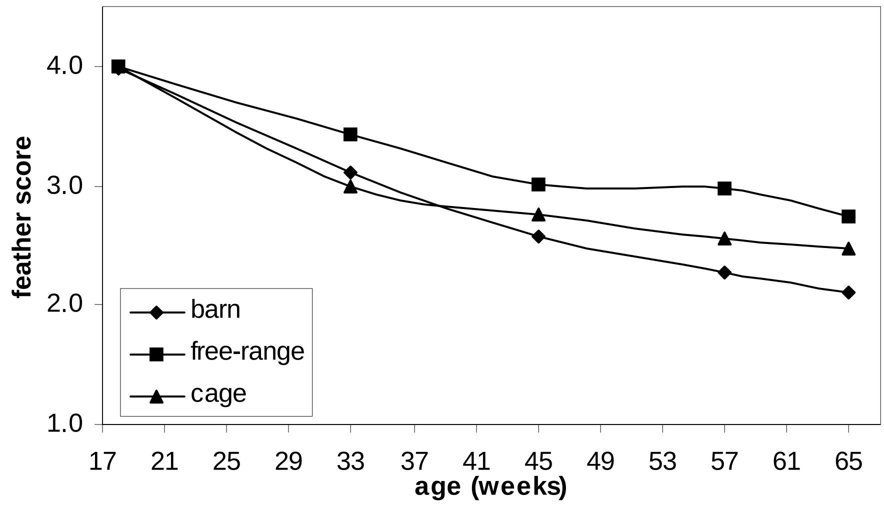

Figure 80. Effect of system on breast feather score.

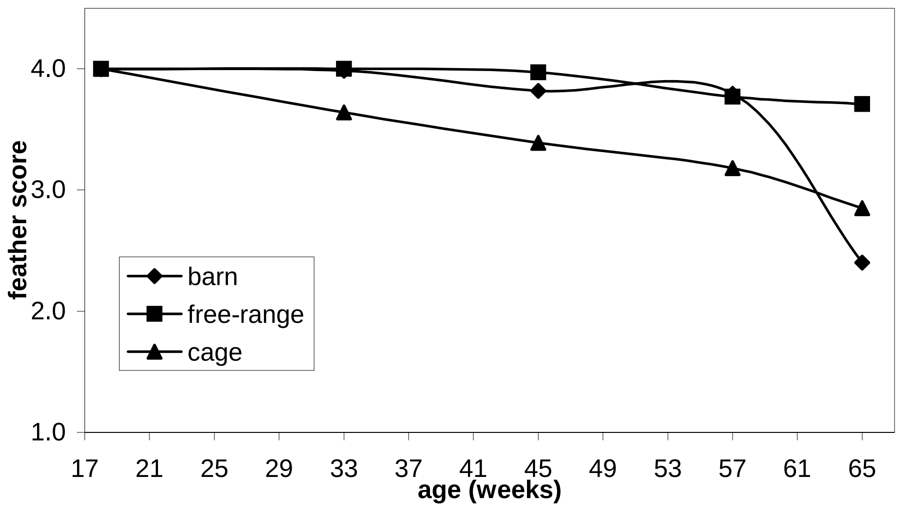

Figure 81. Effect of system on wing feather score.

Cage had the highest tail feather score until week 65 (2.27), when barn score increased to 2.70. Until week 65 barn and free-range had similar tail feather scores. Free-range finished with a tail feather score of 2.03 (figure 82). Foot score (combined toe pad hyperkerotosis, bumble foot and claw length) did not differ for the three systems for the duration of the trial. The scores were never below 3.90 for any system during the trial (figure 83). Linear regressions were performed to investigate the relationship between various production parameters. All of the relationships were positive, however the relationship between blood stained eggs and mortality was not strong (table 9).

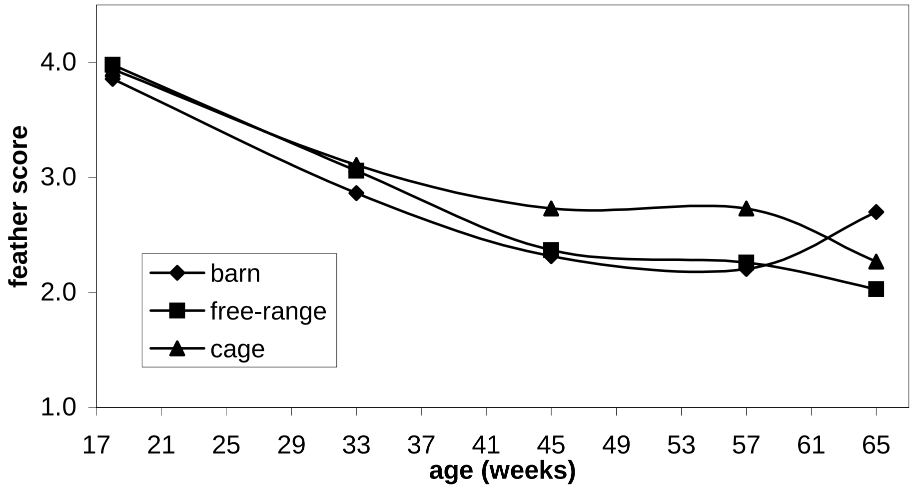

Figure 82. Effect of system on tail feather score.

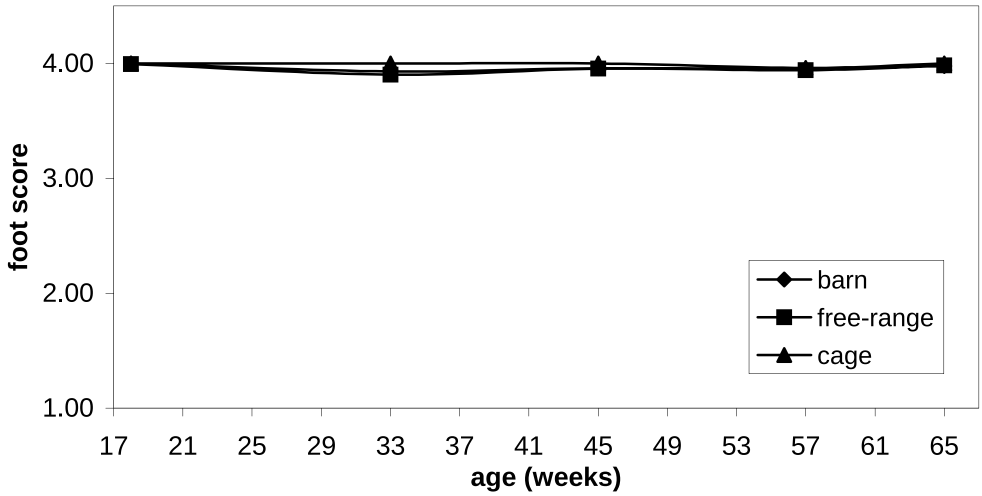

Figure 83. Effect of system on total foot score.

Table 9. Effect of layer system on relationship between blood stained eggs and mortality, blood stained eggs and egg weight, blood stained eggs and bird weight, and bird weight and egg weight. R^2 in bold are > 0.500.

System	Cage		Barn		Free Range	
Factors	**Relationship**	**R^2**	**Relationship**	**R^2**	**Relationship**	**R^2**
Blood Stained Eggs V Mortality	+	0.207	+	0.136	+	0.085
Blood Stained Eggs V Egg Weight	+	**0.522**	+	**0.890**	+	**0.596**
Blood Stained Eggs V Bird Weight	+	**0.511**	+	**0.875**	+	**0.818**
Bird Weight V Egg Weight	+	**0.847**	+	**0.792**	+	**0.826**

4.4 Beak trim within barn

After birds were beak trimmed during the third month of the trial, the untrimmed birds had higher egg weights than trimmed birds. Both groups egg weight peaked at week 53 with untrimmed 67.79 grams and trimmed on 67.61 grams. This was the closest that the treatments got during the trial (figure 84).

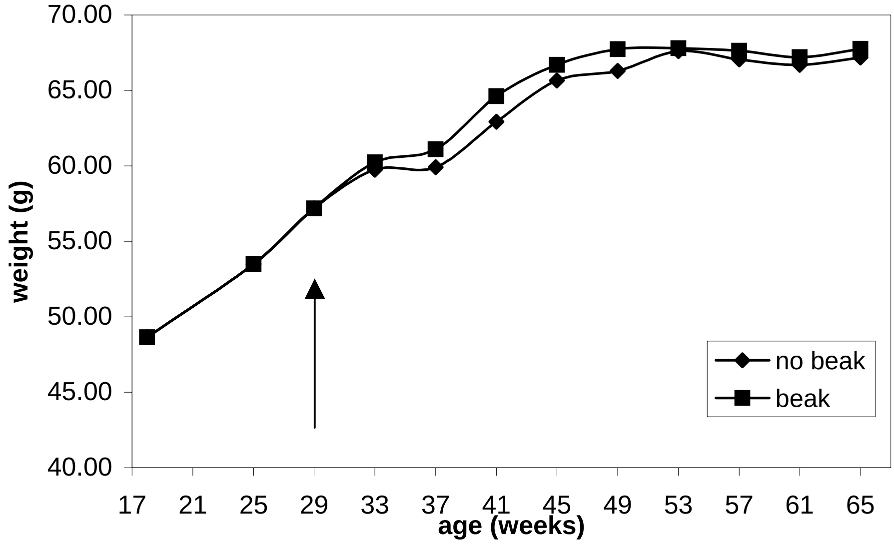

Figure 84. Effect of beak trim on egg weight in a barn layer system (arrow indicates age beak trimming was undertaken).

Trimmed birds had a higher laying percentage from week 33 to week 61, peaking at week 41 with 81.3%. Untrimmed peaked later in the trial (53 weeks) with 79.4% (figure 85).

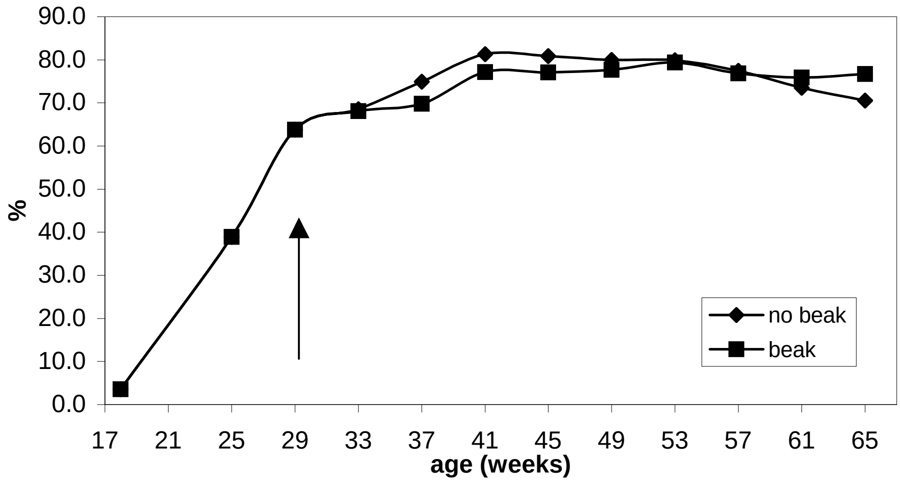

Figure 85. Effect of beak trim on laying percentage in a barn layer system (arrow indicates age beak trimming was undertaken).

Untrimmed had a higher percentage of blood stained eggs than trimmed throughout the trial. Untrimmed peaked at 7.3% at week 41 and spent five months with a percentage greater than 5%. Trimmed percentage of blood stained eggs peaked later in the trial with 4.2% (week 57) with five months greater than 3% but only one above 4% (figure 86). Untrimmed had a higher feed conversion ratio during the trial finishing on 2.84 with trimmed finishing on 2.78 (figure 87). Directly after beak trimming bird weight decreased, however by week 45, trimmed had caught up and by week 57, bird weight of trimmed was higher. Both treatment groups peaked at 57 weeks with trimmed, 2008.3 grams and trimmed, 1950.7 grams (figure 88).

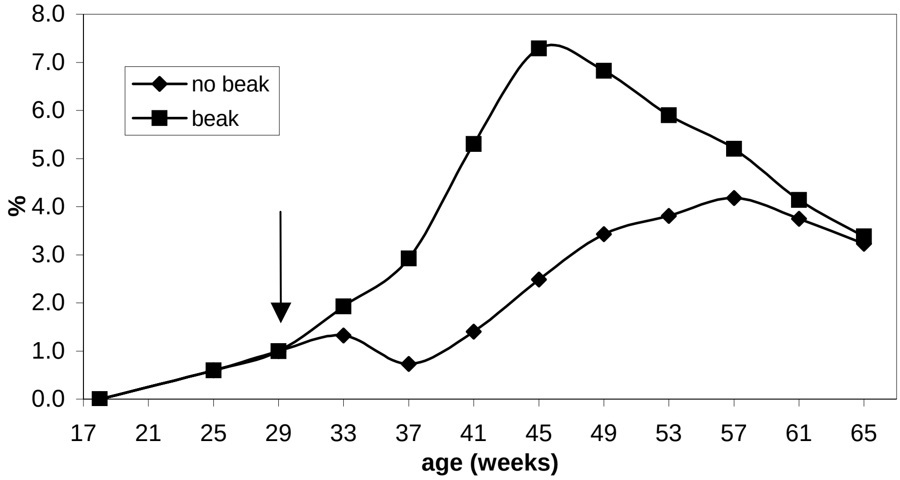

Figure 86. Effect of beak trim on percentage of blood stained eggs in a barn layer system (arrow indicates age beak trimming was undertaken).

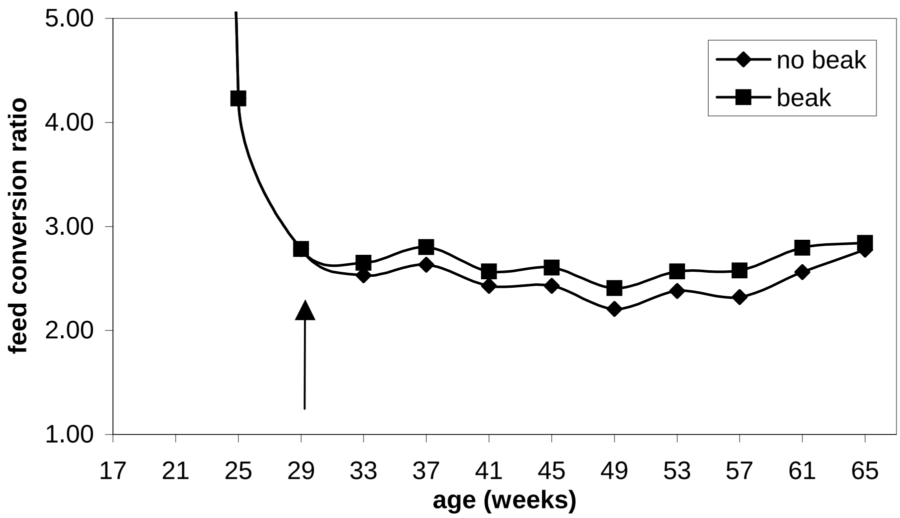

Figure 87. Effect of beak trim on feed conversion ratio in a barn layer system (arrow indicates age beak trimming undertaken).

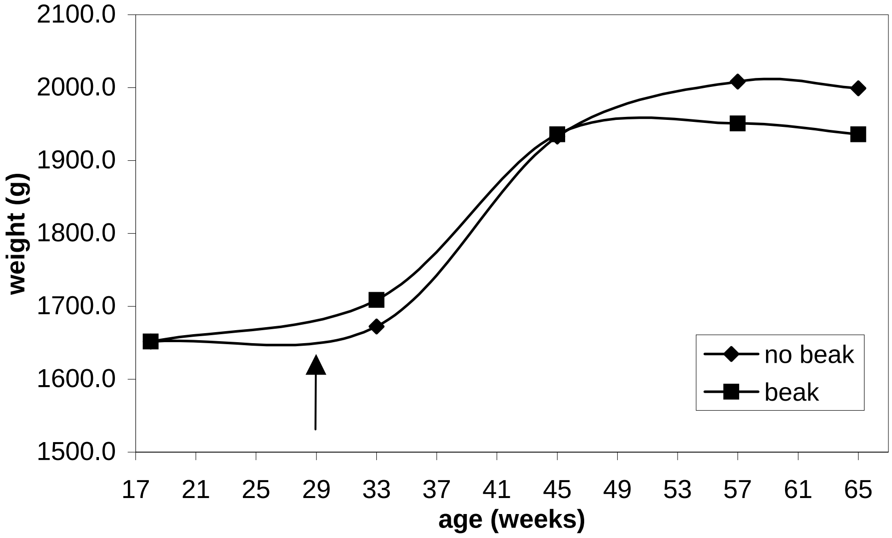

Figure 88. Effect of beak trim on bird weight in a barn layer system (arrow indicates age beak trimming undertaken).

Untrimmed birds mortality peaked at 11.9% at week 33, directly following beak trimming of the other birds. Mortality of beak was greater than 5% for five months of the trial. Trimmed mortality (%) did not reach the level (4.9%) that was attained prior to beak trimming during the remainder of the trial (figure 89).

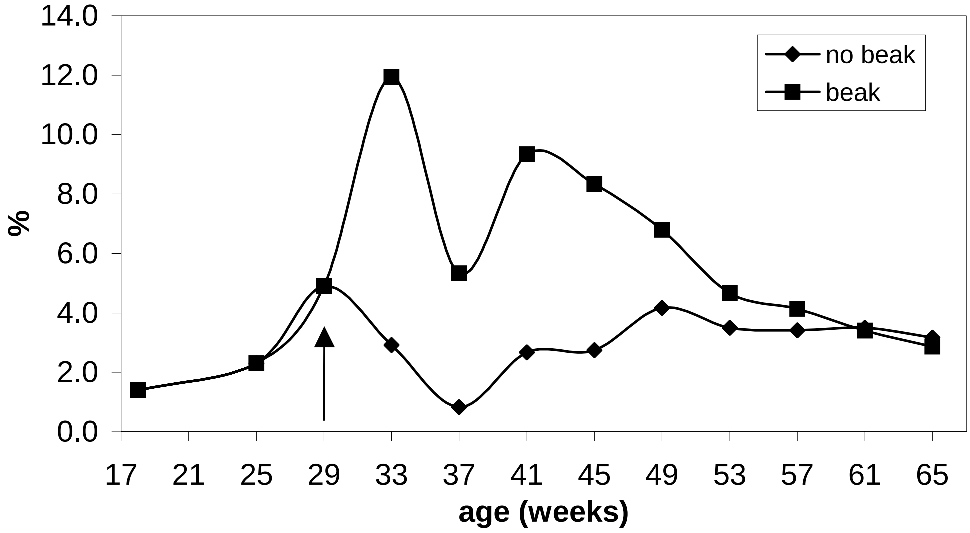

Figure 89. Effect of beak trim on mortality in a barn layer system (arrow indicates age beak trimming undertaken).

Trimmed total bird feather score was higher throughout the trial however by week 65 both treatment groups were very similar. Trimmed finished on a total bird feather score of 2.31 with untrimmed, 2.25 (figure 90).

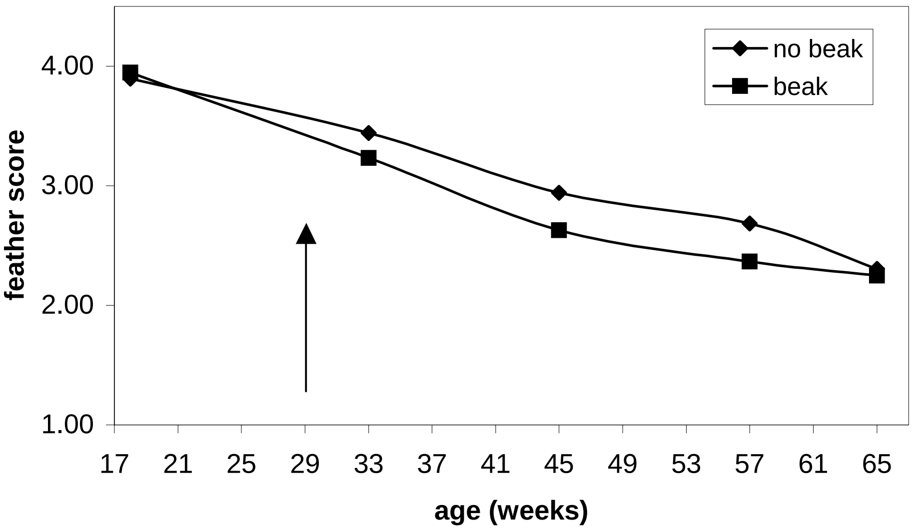

Figure 90. Effect of beak trim on total bird feather score in a barn layer system (arrow indicates age beak trimming undertaken).

Trimmed had a higher neck feather score during the trial, however by week 65 the two treatments had very similar scores (2.14 – no beak and 2.02 – beak) (figure 91). Untrimmed had a lower back feather score throughout the trial. From week 57 to week 65, both treatments score increased, with trimmed finishing on 2.06 and untrimmed, 2.03 (figure 92). Breast feather score followed the same trend as neck feather score with trimmed having a higher score throughout the trial and final scores being very close. Trimmed had a breast feather score of 2.11 at week 65 and untrimmed, a score of 2.06 (figure 93).

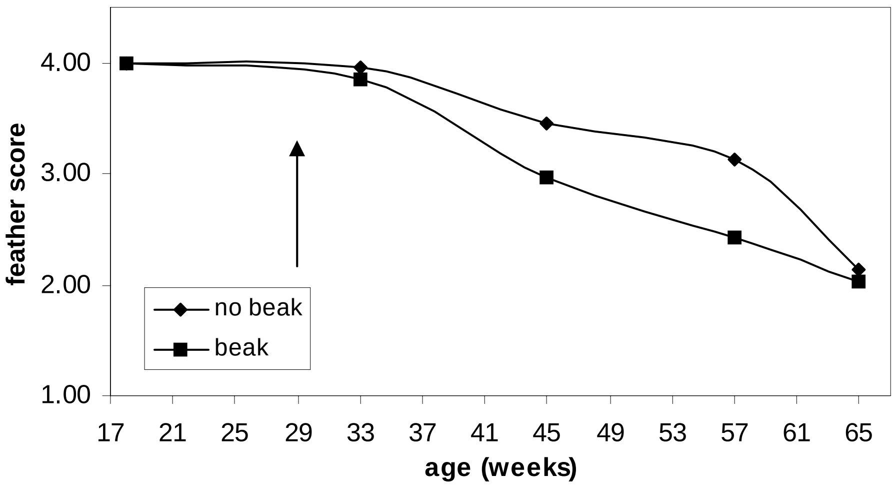

Figure 91. Effect of beak trim on neck feather score in a barn layer system (arrow indicates age beak trimming undertaken).

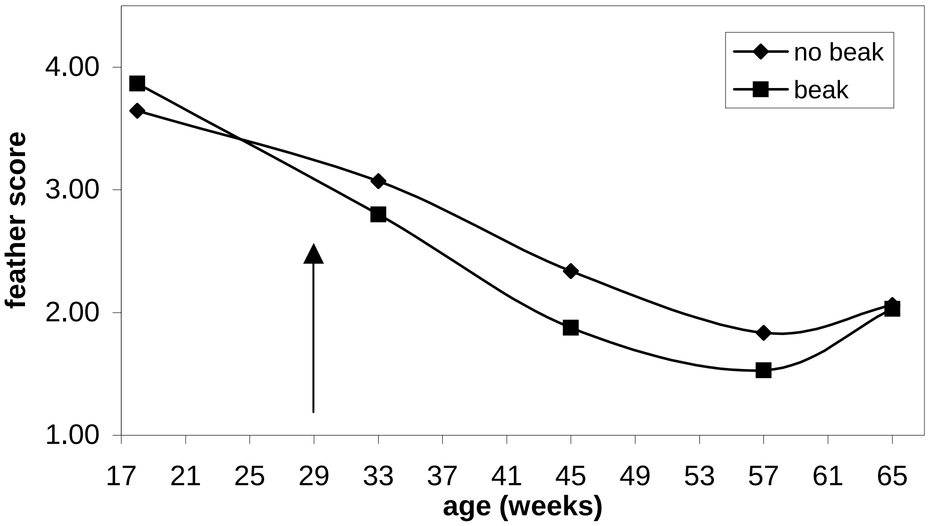

Figure 92. Effect of beak trim on back feather score in a barn layer system (arrow indicates age beak trimming undertaken).

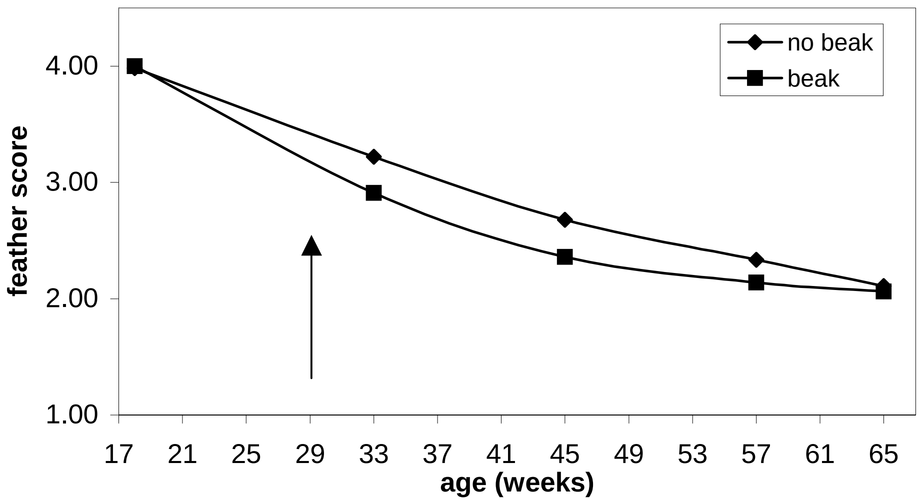

Figure 93. Effect of beak trim on breast feather score in a barn layer system (arrow indicates age beak trimming undertaken).

Wing feather scores were very similar for the two treatment groups during the trial with trimmed slightly higher throughout. From week 57 to week 65, both groups experienced a sharp decrease in wing feather score. Trimmed had a score of 2.47 at week 65 and beak, 2.40 (figure 94).

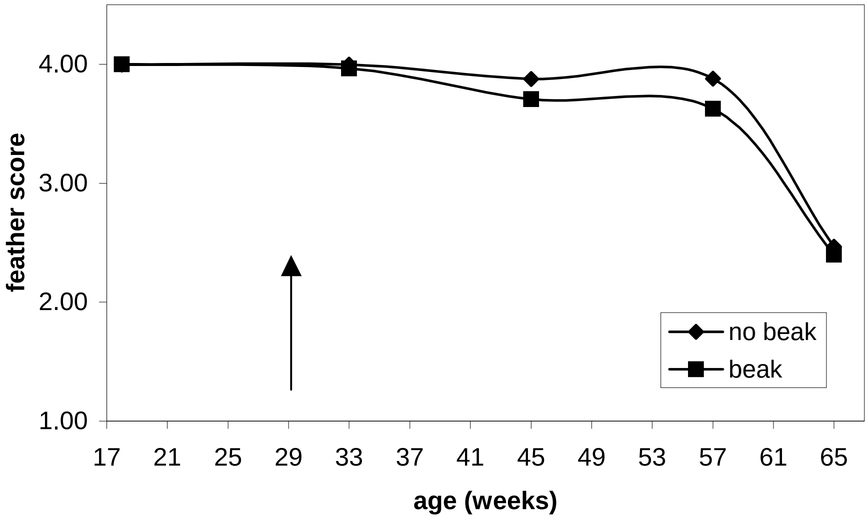

Figure 94. Effect of beak trim on wing feather score in a barn layer system (arrow indicates age beak trimming undertaken).

Trimmed had a higher tail feather score throughout the trial, however scores were very similar at week 65. Both treatment groups tail feather score increase from week 57 to week 65 with trimmed finishing on 2.75 and untrimmed, 2.72 (figure 95).

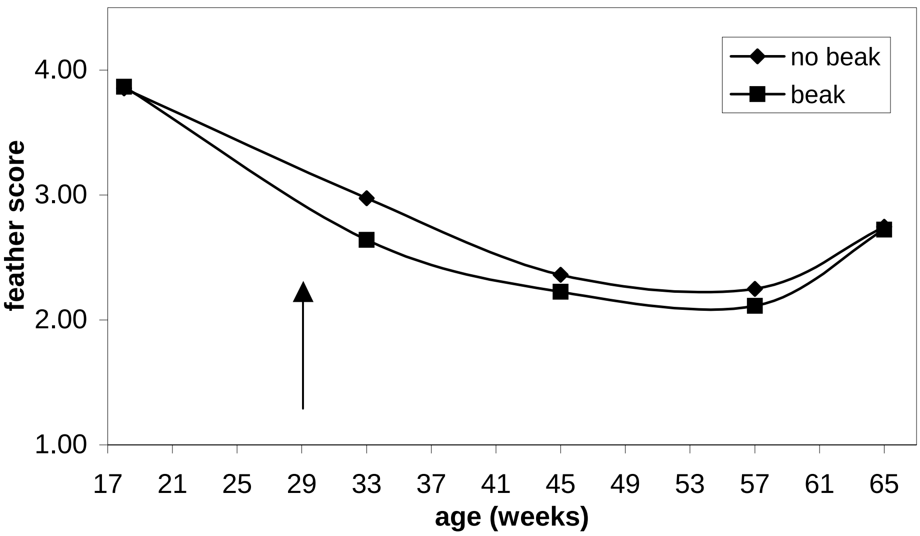

Figure 95. Effect of beak trim on tail feather score in a barn layer system (arrow indicates age beak trimming undertaken).

Foot score (combined toe pad hyperkerotosis, bumble foot and claw length) did not differ for the two treatments for the duration of the trial. The scores were never below 3.93 during the trial (figure 96). Linear regressions were performed to investigate the relationship between various production parameters. All of the relationships were positive, however the relationship between blood stained eggs and mortality was not strong (table 10).

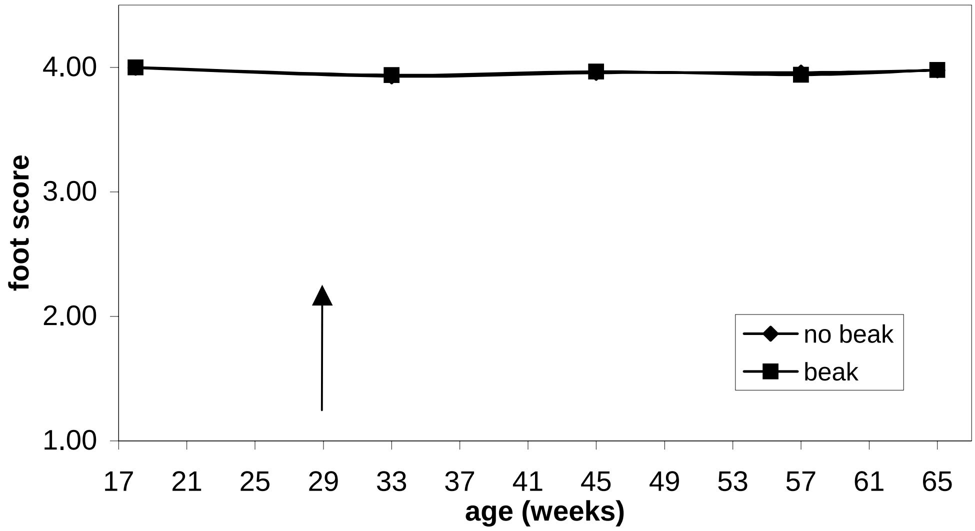

Figure 96. Effect of beak trim on foot score in a barn layer system (arrow indicates age beak trimming undertaken).

Table 10. Effect of beak trim on relationship between blood stained eggs and mortality, blood stained eggs and egg weight, blood stained eggs and bird weight, and bird weight and egg weight in a barn layer system. R^2 in bold are >0.500.

Beak Trim	**Yes**		**No**	
Factors	**Relationship**	**R^2**	**Relationship**	**R^2**
Blood Stained Eggs V Mortality	+	0.223	+	0.162
Blood Stained Eggs V Egg Weight	+	**0.801**	+	**0.756**
Blood Stained Eggs V Bird Weight	+	**0.854**	+	**0.753**
Bird Weight V Egg Weight	+	**0.737**	+	**0.891**

Directly after birds were beak trimmed, untrimmed percentage of eggs laid in nest boxes decreased from 78.1% to 43.4%. Trimmed percentage of eggs laid in nest boxes increased slightly (78.1% to 79.4%) during the same period. Trimmed had a higher percentage of eggs laid in nest boxes until week 57, with untrimmed peaking at 96.0% (week 65) and trimmed, 90.3% (week 65) (figure 97).

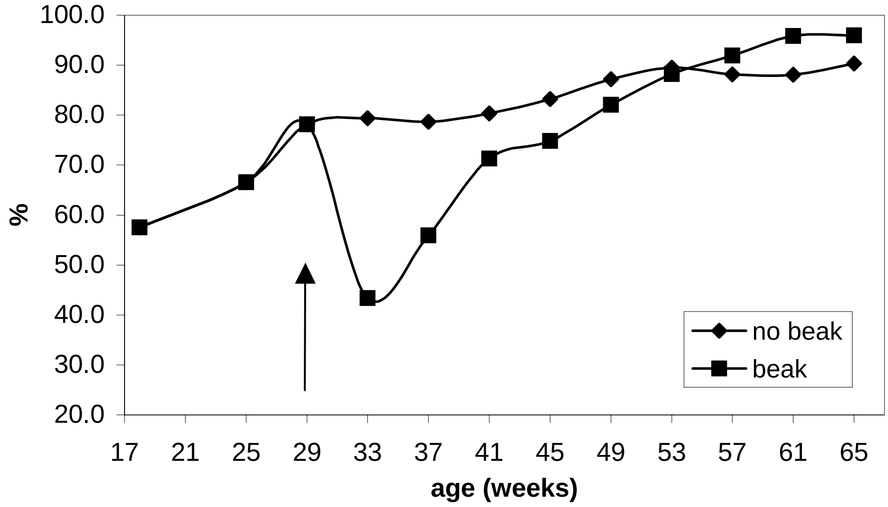

Figure 97. Effect of beak trim on percentage of eggs laid in nest boxes in a barn layer system (arrow indicates age beak trimming undertaken).

5. Discussion

Two concurrent 12-month trials were completed to compare the strengths and weaknesses of three popular brown-egg strains when housed in barn and free-range conditions. Production characteristics were compared to determine which strain, if any, was most appropriate for each system.

5.1 Strain within system, strain between system and system

When comparing barn, free-range and cage systems, Lu and Dingle (1999) found that the average egg weight of barn layers was significantly higher than that of free-range and cage layers. The average free-range egg also tended to be heavier than the cage eggs (Dingle 1998, Lu and Dingle, 1999). This result concurred with the present trial with barn and free-range egg weight greater than cage egg weight when strain between systems and overall systems were compared.

Barnett (1998) and Thomas *et al*. (2000) found no difference in egg weight when comparing barn and cage systems, while Koelkebeck *et al*. (1987) found that cage birds had heavier egg weights than floor pen birds.

In the present trial, Isa had the heaviest eggs in the barn and free-range systems, followed by Hyline, and HiSex with the lightest. According to the strain management guides for each strain Hyline should produce the heaviest eggs, followed by HiSex and then Isa. However because extensive production systems were in use the productive output will vary from published standards.

Cage had a higher laying percentage than barn and free-range during the present trial. Barnett (1998, 1999) compared hens housed in commercial barn and cage systems and found that barn egg production was lower than cage egg production. Lu and Dingle (1999) also found that mean egg production for barn was less than for cage, and that free-range birds also had lower egg production when compared to cage, with Koelkebeck and Cain (1984) and Koelkebeck *et al*. (1987), also finding caged hens had greater egg production rates than floor and range birds.

In the barn system Hyline had the highest egg production, followed by Isa and HiSex, while in the free-range system, Isa had the highest egg production followed by HiSex and Hyline. According to the layer management guides for each strain, production should have been over 80% by 23 weeks. In the barn, Hyline reached 80% by 41 weeks, Isa by 49 weeks and HiSex never reached 80% production. In the free-range system, Hyline reached 80% by 45 weeks, Isa by 41 weeks and HiSex 41 weeks. However because extensive production systems were in use the productive output will vary from published standards.

In a controlled environment shed it was found that the incidence of blood stained eggs was the highest in the early lay period immediately following a period where the flock experienced a period of weight loss (Parkinson and Cransberg, 2002). In the present trial, when systems were compared barn hens had the highest percentage of blood stained eggs during the trial, followed by free-range and cage. Barn and free-range blood stained eggs increased from week 37. From week 18 to week 33, barn bird weight only increased by 23.7 grams and, while free-range bird weight increased by 119 grams in the same period, both systems started with a lower initial weight than cage birds (barn – 1660g, free-range – 1654g and cage – 1694g). Parkinson and Cransberg (2002) found that those birds that produced a blood stained egg were generally 50 grams lighter than those birds that did not. A higher egg weight to 32 weeks may indicate a relationship between small birds and large egg size that is contributing to the incidence of cloacal haemorrhage (Parkinson and Cransberg, 2002). The results of the present study showed that free-range and barn did have heavier eggs than cage birds at week 32 and although free-range had the heaviest eggs throughout the trial, barn had a lower bodyweight and higher blood stained eggs. Strong positive relationships were found between blood stained eggs and egg weight and blood stained eggs and bird weight.

When strains were compared between systems, Hyline and HiSex strains had the highest percentage of blood stained eggs in the barn, with Isa having more blood stained eggs in the free-range system. All strains had a very low percentage of blood stained eggs in the cages.

Yolks of free-range eggs should be darker because of the supplementary natural pigments the birds obtain from the green pick (Dingle, 1998) with yolk colour score lower in the barn than in the cage system (Barnett, 1998, 1999). In the present trial no differences were found in the yolk colour of all three systems. This could have been because all three systems received the same diet and the free-range birds did not eat much green pick from the range.

In the present trial, cage had the lowest feed conversion ratio of the three systems during the trial, with barn and free-range having very similar feed conversion ratios . Feed efficiency has been found to be poorer for floor and range birds when compared to cage birds (Koelkebeck and Cain, 1984, Koelkebeck *et al.*, 1987, Lu and Dingle, 1999). However, Thomas *et al.* (2000) found that cumulative feed conversion ratio in the barn and cage systems was not influenced by housing system, with feed conversion ratio in the barn and cage systems 2.36 and 2.25, respectively.

Isa had the lowest feed conversion ratio in the barn and free-range systems, with HiSex the highest in the barn and Hyline the highest in the free-range.

Free-range had the heaviest bird weight of the three systems, followed by cage birds. Hughes and Dun (1986) found hens from four successive flocks were heavier on free-range than in cages. The authors found crude differences may conceal differences in body composition: hens on range had heavier alimentary tracts, greater muscle mass and more plumage, but lighter in livers and less body fat. In the present trial, barn birds had a lower body weight when compared to cage birds, with Koelkebeck and Cain, 1984, Koelkebeck *et al.*, 1987, and Barnett, 1998 and 1999, also finding that bodyweight was greater for caged birds compared to barn birds. Barnett (1999) suggests possible reasons for this include inadequate dietary composition, inadequate feeder places and /or a change in social behaviour around the feeders resulting in displacement and/or food wastage.

Appleby *et al*. (1988) found that bird weight increase was initially faster in birds on litter, however caged hens were equally as heavy by the end of the trial. This result differed from the present trial with cage birds initially increasing faster than the barn and free-range birds, with free-range birds heavier by the end of the trial.

Hyline birds were the heaviest in the barn and free-range system, followed by Isa and HiSex. At 65 weeks, Hyline birds, according to the layer management guide, should have weighed 2000 grams and in the barn weighed 2045grams and 2135 grams in the free-range. Isa birds should have weighed 1950-2050 grams at 65 weeks of age and in the barn weighed 1969 grams and free-range, 2079 grams. HiSex birds 65 weeks of age should have weighed 2040 grams, and weighed 1919 grams in the barn and 1991 in the free-range. Hyline and Isa bird weights were above the layer management guide recommendations however because extensive production systems were in use the productive output will vary from published standards.

Free-range had the highest mortality (%) of the three systems, followed by barn and cage. Early in the present trial barn and free-range birds had bodyweights below that of the cage birds (weeks 18 – 33). In commercial barn systems, mortality was markedly increased in flocks that did not reach the appropriate body weights at 26-29 weeks of age (Parkinson and Cransberg, 2002). The authors found that as body weight of pullets increased egg production also increased and mortality decreased. Diagnostic studies of under weight flocks indicated problems with egg peritonitis and salpingitis (Parkinson and Cransberg, 2002). In the present trial the barn and free-range systems also had problems with egg peritonitis and salpingitis. The risk of disease spread by contact between birds, or by contact between birds and faeces, is generally regarded as more severe in non-cage systems (Appleby and Hughes, (1991). Salpingitis (inflammation of the oviduct) is found considerably more frequently in birds on litter than in cages (Lindgren, 1978).

Vent pecking and cannibalism could have been another reason for the higher mortality in the free-range and barn systems. In cases where flocks in alternative systems have been compared directly with cages and no problems such as cannibalism or disease occurred, mortality was generally similar (Appleby and Hughes, 1991). When cannibalism did occur, mortality could be disturbingly high (in some cases 25% or more) (Appleby and Hughes, 1991). Keeling *et al*. (1988) found in a large free-range flock cannibalism became severe after 11 months of lay, with most losses occurring in the final eight weeks. When comparing barn and cage systems, Thomas *et al*. (2000) found that although mortality in both cage and barn system was within the acceptable limits; it was significantly higher in the barn.

During month eight of the trial, all strains of the cage birds experienced a spike in mortality (Hyline, 9.1%, Isa, 4.5% and HiSex, 16.4%). All strains received the same diet from the same batch of feed; therefore the feed may have influenced this spike in mortality. A new diet can cause a reduced or increased palatability of the food and therefore result in decreased intake or in increased competition for food, leading to stress and frustration which are reported risk factors in vent and feather pecking (Pötzsch *et al*., 2001). A new diet may also cause diarrhoea, leading to an inflamed and reddened vent and soiled surrounding, attracting pecking from flock-mates. However, all hens in the trial (barn, free-range and cage) were fed the same batch of feed with only birds in cages eight months into lay, significantly affected.

Dead birds were sent to the pathology laboratory for examination (Yeerongpilly Veterinary Laboratory) and the diagnosis was 'cannibalism with no evidence of disease found'. Only one bird out of the eleven birds examined was dehydrated and in poor condition with the other ten 'fat' or 'in moderate nutritional condition'. All of the birds examined showed feather loss. Forceful pecking is directed at exposed skin, often persistently, and this can lead to haemorrhage. The removal of feathers by feather pecking can result in bleeding from the skin or follicles (especially with not fully grown feathers), which may stimulate cannibalism (McAdie and Keeling, 2000). It is also possible that hens which have been denuded by feather pecking, and are lacking the protection of feather cover, are more likely to be victims of cannibalism as their bare skin may be more easily damaged by scratches, pecks and knocks (McAdie and Keeling, 2000). The blood resulting from these injuries may also elicit cannibalistic attacks (McAdie and Keeling, 2000). Damage is severe and can result in death, or the bird has to be culled because of the severity of the injury. The recipient may initially move away to avoid pecking but the peckers tend to follow and eventually it gives up and apparently submits to the pecking. In cages, however birds are unable to escape attention of the pecker.

Bilčík and Keeling (1999) found that there was a significant negative association between the number of aggressive pecks received and body weight. Hyline birds were the heaviest of the cage birds, followed by Isa and HiSex. HiSex birds did have the highest mortality (16.4%), however Hyline were the heaviest birds and had the second highest mortality (9.1%). Isa had a body weight less than 60 grams heavier than HiSex, however Isa mortality peaked at only 4.5%. Temperatures were normal in the shed for that time of year and ranged from 22º C to 12º C.

In the barn and free-range systems HiSex had the highest mortality, followed by Isa and Hyline.

Feather cover of laying hens declines as the hen ages and by the end of lay some hens are almost naked (Tauson, 1984). Extensive feather loss (apart from moulting) does indicate major physiological or behaviour differences from natural conditions, is unattractive to the human observer and may increase the danger of exposed skin being injured (Appleby and Hughes, 1991).

In the present trial, total bird feather score was similar for all three systems, with barn having a slightly lower feather score than cage and free-range. By 65 weeks free-range had the highest total bird feather score, followed by cage and then barn. These results were similar to Barnett (1998) who found that there were no overall differences in barn and cage overall (total) feather condition and for all areas, feather condition and cover declined overtime. Appleby *et al*. (1988) found that feather loss is generally worse in cages than other systems, with Hughes and Dun (1986) finding free-range feather damage less than in cages.

Isa had the highest total feather score in the barn (figure 98) and free-range systems, followed by Hyline and HiSex (figure 99).

Glatz (2001) found that feather score was highly correlated with feed intake. The results of the present trial suggest that as feather cover decreased feed intake increased in the barn and free-range systems, however the cage birds' feed intake decreased. This could be due to the different regions of the body that were affected in each system. In the barn and free-range systems the back and tail areas had lower feather scores than the cages. A denuded back would allow a high loss of heat from the body. Neck feather scores were lower in the cages probably because of abrasion on the wire as birds were feeding and drinking. Wing feather scores were also lower in the cage system. The breast area was most denuded in the barn and cage system, again due to the wire in the cages and the slats in the barn.

Hens lose their feathers over large parts of their body due to feather pecking or poor beak trimming, abrasion and moulting (Glatz, 2001). Feather loss can also be related to stocking density. When comparing a deep litter system and cage system for egg production the severity of feather damage and loss was correlated with stocking density, being worse at higher densities (Appleby *et al*., 1988). Stocking densities in the present trial were within the recommended limit for each system.

Figure 98. Isa feather condition in barn system at 55 weeks.

Figure 99. HiSex feather condition in barn system at 55 weeks.

Feather loss from abrasion is usually worse in cages, but the main reason for loss in all systems is feather pecking (Hughes, 1985). Appleby *et al.* (1992) found the most common area to be pecked, initially, is the back, perhaps because feathers out of line in more accessible places are easily preened. While Bilčík and Keeling (1999) reported that the belly region became denuded first, although there were fewer pecks directed there than to some other body parts. Apart from these feathers being easy to remove, the target birds were often sitting on perches, providing easy access to the belly from the ground (Bilčík and Keeling, 1999). Koelkebeck *et al*. (1987) found that there were no significant differences in feather pecking in cage and floor birds, however caged hens engaged in more feather pecking with beak trimming reducing feather damage on litter but having no effect in cages (Appleby *et al*., 1988).

Feather pecking is one of the most serious behavioural problems in commercial laying hens, occurring in both caged birds and birds kept in floor systems. Feather pecking is the pecking at, or plucking feathers from, a conspecific (Pötzsch *et al*., 2001). It is characterised by poor quality plumage, patches of feather loss and damage to the skin (Pötzsch *et al*., 2001). McAdie and Keeling (2000) suggest that feather pecking is a problem particularly in loose-housing systems where many hens can be affected by only a few feather peckers. Feather pecking can become an even larger problem if it spreads throughout the flock. The advantage of greater behavioural expression in alternative systems is limited by behavioural problems that negatively influence animal welfare (Pötzsch *et al*., 2001). In the flock feather pecking may result in increased mortality, decreased egg production and increased food consumption (Appleby *et* al., 1992, Pötzsch *et al*., 2001). Heat loss from defeathered birds can lead to more than 40% higher energy needs or 27% greater food consumption (Bilčík and Keeling, 1999).

Feather pecking can also be considered a welfare problem because it has been suggested that it can lead to cannibalism (Allen and Perry, 1975). Appleby *et al*. (1992) agrees that cannibalism sometimes follows on from feather pecking, for example when exposed skin is injured, but it more often arises individually. Gunnarsson *et al*. (1999) found no significant correlation between cloacal cannibalism and feather pecking agreeing with previous findings in the literature that feather pecking is separate from pecking associated with cloacal cannibalism (Hughes and Duncan, 1972). Cannibalism has been defined in many ways, the most objective describing it as the "pecking and tearing of the skin and underlying tissues of another bird" (Keeling, 1994). In hens, the most common form is vent pecking.

Foot and claw damage are often a major problem in cages, with lesions, fissures and hyperkeratosis on the feet and with twisted, broken or overgrown claws (Tauson, 1980). Some similar problems can also occur in slatted systems, and may be reduced by the provision of perches, but in general hens with a variety of substrates (solid, friable, perches) have good foot condition (Appleby and Hughes, 1991). In the present trial there were no differences in foot score between systems and within strains.

Lu and Dingle (1999) found that the use of nest boxes in barn and free-range layer systems increased every week over the trial. The present trial showed similar results with Hyline laying the most eggs in the nest boxes in the barn and free-range systems.

5.2 Beak trim within barn

In the present trial no differences in egg weight and production were found between beak trimmed and non-beak trimmed birds in the barn. Birds that were beak trimmed had a lower percentage of blood stained eggs, which gradually increased towards the end of the trial. The slow increase towards the end of the trial could have been caused by some their beaks starting to grow back. Directly after beak trimming, the birds that did not receive a trim showed a dramatic increase in the percentage of blood stained eggs, which suggests an increase in vent pecking in these birds.

Beak trimmed birds in the barn had a lower feed conversion ratio compared to non-beak trimmed birds. During the present trial, the non-beak trimmed birds had a heavier body weight and produced fewer eggs than the beak trimmed birds. Beak trimmed fowl have a lower rate of mortality, eat slightly less food and have a slightly improved feed conversion ratio (Lee and Craig, 1991). The improved food conversion could be because the birds waste less food (Blokhuis *et al*., 1987), or because they have better plumage so less food is required for maintenance of normal body temperature (Hughes and Michie, 1982, Hughes and Gentle, 1995). In the present trial beak trimmed birds had a higher total feather score until week 65 when both treatment groups were similar.

Directly after beak trimming, beak trimmed birds had a lower body weight, however by week 45 they had caught up to and then passed non-beak trimmed birds. Workman and Rogers (1990) suggest that decreased pecking efficiency of beak trimmed birds was not the only cause of reduced feed intake, but that food consumption was less rewarding for beak trimmed birds.

Mortality of birds that weren't beak trimmed in the barn increased dramatically the month following beak trimming. This was probably also due to vent pecking and cannibalism. Birds that were beak trimmed had a lower mortality than before they were trimmed for the remainder of the trial.

After beak trimming, the number of non-trimmed birds using nest boxes decreased. This could be due to increased vent pecking and cannibalism in the nest boxes. Vent pecking appears to be a separate behaviour pattern for the previous one. Vent pecking is characterised by damage to the cloaca, and the surrounding skin and underlying tissue by a conspecific and can progress to evisceration and death (Pötzsch *et al*., 2001). It generally occurs soon after the birds have come into lay and may be linked to hormonal changes at the time (Pötzsch *et al*., 2001). It may be especially likely when birds in floor systems lay their eggs on the floor in crowded areas. Initiated when a minor partial prolapse of the uterus occurs immediately after oviposition, and exposure of the mucous membrane stimulates pecking by other birds. It may begin as investigatory pecking but can quickly escalate and the affected bird may die from loss of blood. The pecking may continue and has been called 'pick-out', in which the abdominal organs can be removed.

One situation in which this starts is when a hen has just laid an egg in a nest box, facing inwards and the vagina is still partly everted (Appleby *et al*., 1992, Savory, 1995). Other hens waiting to lay, investigating the nest box and the hen in it, peck at the soft, red vent area. If the skin is broken, here or elsewhere on the body, other birds then join in the pecking, because these species of birds are attracted to blood. Further pecking and consumption of flesh then frequently result in death (Appleby *et al*., 1992). The aspect that is least understood is that the pecked bird often makes surprisingly little effort to escape despite the fact that it is likely to be in severe pain (Appleby *et al*., 1992). Sometimes this may be because the pecked bird is a low ranking individual that has been pecked aggressively so often that it has learned it cannot escape. In contrast to feather pecking, cannibalism is more common in non-cage systems than in cages.

Following the comparison of the strengths and weaknesses of the performance of Isa, Hyline and HiSex birds in barn and free-range systems, the present trial found that Hyline and Isa were best suited to the free-range system and Isa, to the barn system. However the mortality rates were unacceptable for all three strains in both systems. Mortality was decreased dramatically after beak trimming in the barn in the present trial however beak trimming is not wholly effective at preventing feather pecking and cannibalism, and there is continuing public concern that it may cause chronic pain. If we are to reduce the need for beak trimming in the Australian flock further research needs to be done to develop a specific strain for each system or improved management and environmental practices need to be undertaken.

6. Implications

- This project has identified some of the advantages and disadvantages of barn, free-range and cage layer systems. Egg weight and bird weight are higher in the barn and free-range systems, however egg production, percentage of blood stained eggs, mortality and feed conversion ratio were superior in the cage system.

- Hyline and Isa birds were more suited to the free-range system compared to HiSex birds. Isa birds were more suited to the barn system compared to Hyline and HiSex birds.
- Beak trimmed birds in the barn system had lower mortality, lower percentage of blood stained eggs and a lower feed conversion ratio compared to non-trimmed birds. If we are to reduce the need for beak trimming in the Australian flock further research needs to be undertaken into this area.
- The mortality rate was unacceptable for all strains in the barn and free-range systems therefore it would be hard to recommend any particular strain as being barn and/or free-range 'friendly'.

7. Recommendations

- Development of a specific breed for use in alternate systems. A more docile breed than the three investigated in the present trial would be better suited to extensive farming.
- Improvement of the management procedures for current commercial breeds for use in alternate systems.

- Ensure dietary requirements are being met so that bird weight is at appropriate level during early lay to decrease the number of blood stained eggs.

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