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Productivity and profitability of caged layers with poor feather cover

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Foreword

For many years farmers have been aware that birds with poor feather cover have been consuming more food. However, there has been no information available in Australia from commercial flocks to quantitate the increase in feed intake with the feather condition of the flock. In practise layers are housed in groups of 3-5 and studies on feather cover, food intake, efficiency and energy metabolism have invariably been carried out with single birds placed in respiration chambers. Research findings indicate that food consumption could be 10-30% higher in hens with the poorest plumage. Relevance of this research data under field conditions in Australia needs to be confirmed because birds in groups can huddle together to minimise the impact of drafts and cold weather.

The poultry farmer needs to know whether maintaining hens with poor feather is economically viable. If not, then consideration should be given to replacing these hens earlier or utilising strategies to improve the feather cover. Before the farmer adopts these strategies information was required to determine whether feather cover influences the profitability of the flock. In Australia 50% of the national flock are old hens with deteriorating feather cover. During winter these hens could be consuming millions of dollars of additional feed.

The research described in this report evaluated the productivity, efficiency and profitability of 2 strains of commercial layers (Tegel Tint and Tegel Brown) housed at four per cage in Harrison 'Welfare' back-to-back, single tier cages (each 500 mm wide by 545 deep; 600 cm^2/bird) maintained over the temperature range of 13-17^{0}C. Hens were allocated to cages on the basis of their feather score. For the experimental phase (91-98 weeks) there were four treatments, 2 strains and 2 feather cover treatments (poor feather cover and good feather cover). A randomised design was used for allocation of treatments with 22 replicates per treatment.

The results showed that the Tegel Brown heavy strain with poor feather cover consumed an extra 23g/hen/day or 19% more food than birds with good feather cover (119.7g/day versus 142.5g/day). The Tegel Tint light strain with poor feather cover consumed 119.6 g/day or 11.4% more food than hens with good cover (107.4g/day). Feed conversion and egg income were superior in hens with good cover. Food intake was highly correlated with feather score. The feather score on the back and vent were the best indicators of the overall feather cover of hens.

These results show clearly that poor feather of layers in winter is causing massive increases in feed costs (about $6m annually) for the Egg Industry.

There is an urgent need for the egg industry to implement strategies to improve the feather cover of hens particularly in winter.

Peter Core
Managing Director
Rural Industries Research and Development Corporation

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Executive Summary

A study was undertaken to evaluate the biological and economic significance of poor feather cover in hens in a commercial poultry house. Previously there have be no studies undertaken in Australia during winter to demonstrate the effects of poor feather cover on production and profitability in a commercial poultry house. The experiment was conducted from July-September 1997 in a layer shed where temperature ranged from 13^0C-17^0C. The trial examined the effect of poor feather cover on production and profitability in two commercial strains of layers (tinted and brown egg) housed at four per cage (600 cm^2/bird) from 91-98 weeks of age. Feather cover was assessed using a 4 point scoring system. An overall feather score was determined by scoring individual body parts to obtain an overall feather score.

Poor feather cover and production

- At the start of the experiment 50% of the birds were classified as having poor feather cover.
- Food intake of hens with poor feather cover was 16% higher than hens with good feather cover.
- Brown egg layers and tinted layers with poor feather cover consumed 19% and 11% more food respectively than hens with good cover.
- Hens with good feather cover produced more eggs and had higher liveweight, but there was no significant difference in egg weight between hens with poor and good feather cover.
- Food per dozen eggs was 27.5% superior in hens with good feather cover.
- There was a trend for birds with poor feather cover to produce more oversized eggs, but fewer extra large eggs than hens with good feather cover.
- Egg income was 8% higher in hens with good feather cover.

Relationships between overall feather cover, body part feather scores and feed intake

- Feather cover on back and vent were the best indicators of overall feather score.
- The tail, base of tail and vent were the body parts most effected in birds with poor feather cover.
- Overall feather score was highly correlated with food intake.
- Poor feather cover on neck and back were the best indicators of hens with high food intake.

Husbandry finding associated with poor feather cover

- Birds housed together at the start of the experiment with poor feather cover showed an improvement in feather cover after 8 weeks of the experiment. The opposite occurred in birds with good feather cover. They showed a decline in feather cover at the end of the experiment.

General Introduction

For many years farmers have been aware that birds with poor feather cover could be consuming more food, but no information has been available in Australia to quantitate the increase in feed intake with feather condition of commercial flocks. This study was undertaken to provide this information by conducting a trial under commercial conditions. Previous research has indicated that food consumption could be 10-30% higher in hens with the most worn plumage. In Australia, a considerable proportion of the national flock are old hens with deteriorating feather cover. During winter (or more particularly when environmental temperatures are below 20^0C) these hens could be consuming millions of dollars of additional feed. This estimate needs to be validated under field conditions.

It is possible that the work published under research conditions on increases in food intake associated with poor feather cover may not be applicable under commercial conditions. It is essential that a more realistic assessment under commercial conditions be made of the influence of poor feather cover on feed intake. If plumage condition does substantially influence the hen's feed requirements, information on best practice to minimise feather loss in poultry can be extended to the Industry.

From the results of this current study egg farmers will be able to determine whether maintaining old hens with poor feather cover is economically viable and whether husbandry strategies to improve feather cover should be implemented.

Objectives

1. To determine if feather cover effects productivity, efficiency and profitability of commercially housed layers in winter.
2. Advise egg industry of the economic implications of maintaining hens with poor feather cover in winter.
3. Provide industry with husbandry strategies to improve feather cover.

CHAPTER I
LITERATURE REVIEW

Feather pecking

Feather pecking has always been a serious problem of poultry. It consists of pecking directed at feathers of other birds, sometimes involving plucking out and eating these feathers. It may result in severe damage of the birds with bare patches and wounds to the skin in more serious pecking attacks eventually leading to death of the bird. Frequency of pecking is high in cages and while cannibalism is generally controlled, feather cover in older hens is quite poor, creating a negative image of the caged hen to the public.

Types of pecking

Aggressive pecks in birds are the most frequent types of pecking observed, followed by allopreens, feather pulls, light pecks and toe pecks. Birds with feather damage received more light pecks, toe pecks and feather pulling than birds without damage (Leonard *et al.* 1995). Recent genetic studies selecting birds for a low tendency to feather peck have produced promising results (Kjaer and Sorensen, 1997; Hester *et al.* 1996; Craig and Muir, 1996).

Feather pecking is a form of redirected ground pecking (Blockhuis 1986, 1989). Ground pecking apart from food gathering is a form of exploratory behaviour serving to gather visual, tactile and gustatory information (Blockhuis and Van Der Haar, 1989). Feather pecking is also considered to be a stereotypic behaviour. Some birds develop very high frequencies while others show very low frequencies (Kostal *et al.* 1992). This may account for the wide variation in the feather cover noted in the field.

Feather pecking during rearing results from the age related decline in foraging activities coinciding with increases in preening and pecking at other birds. Consumption of litter and feathers may be reinforcing with dustbathing enhancing the stimulus of litter which contrasts against the background of plumage colour. This may direct pecking towards the backs of birds where feather as well as litter material is removed. Vestergaard *et al.* (1993) reported that feather pecking was most likely to occur in the Red Jungle fowl when birds were dust bathing or preparing to do so. Severe feather pecks received during dust bathing were correlated with the amount of feather damage on the recipient. Birds that did most feather pecking were the ones that did the least dust bathing and were also the most fearful. Allopreening pecks (gentle pecks) can be easily distinguished from the severe feather pecks and both types of feather pecking are related to social status of the bird.

Regular pecking and feather removal may lead eventually to vent pecking as the bird matures (Savory and Mann, 1997). Housing conditions that promote foraging behaviour are effective in reducing and preventing feather pecking (Hubereicher and Wechsler, 1997). Norgaardnielsen (1997) recommends that chicks need access to sand in the first 3 weeks of life to encourage dust bathing behaviour and to reduce feather pecking. Sanotra *et al.* (1995) suggest that there is a high risk for the development of pathological feather pecking development when straw or wood-shavings are used as litter for young chicks. In layers, risk of feather pecking is increased by feeding pellets and decreased by feeding mash (Lindberg and Nicol, 1994). Plumage deterioration seems to occur more frequently in fully coloured birds than in white birds or those with light undercolour (Merat *et al.* 1979)

Plumage cover and metabolic rate

The hen has a high body temperature which it keeps constant by regulating blood flow through the comb, wattles and feet and by vaporisation of water via respiration (Freeman, 1971). It is well known that feather cover of laying hens declines as the bird ages (Tauson, 1986). By the end of a lay some hens are almost naked. When hens lose their feathers over large parts of their body due to feather pecking, abrasion and moulting there is a decline in their natural heat insulation and increase in convective heat loss from the bird (Mitchell, 1985). Metabolic rate of Leghorn cockerels at 22^0C was 85% higher for completely naked birds than for those with normal feathering (O'Neil *et al.* 1971). Dwarf laying hens with naked necks show a 25% increase in heat production at night and 13% during day (Herremans *et al.* 1988) compared to the full feathered birds maintained at 10^0C. Nichelman *et al.* (1986) showed the maximum themoregulatory increase in heat production of defeathered laying hens exceeded that of the feathered ones at thermoneutral temperatures by 238%. Nearly naked birds show a difference in fasting metabolic rate of 8 kJ/h at night and 11 kJ/h during day Damme *et al.* (1987). There is evidence, however, that metabolic rate of birds in animal chambers may be an over estimate of actual heat production (Johnson and Farrell, 1983). Changes in behaviour may affect feeding patterns and cause modifications to group structure which could influence food intake. Thus research findings on the level of increases in metabolic rate and feed intake as a result of poor feather cover might be an overestimate of the situation on commercial layer farms.

Plumage cover and diet

In brown layers, Biedermann *et al.* (1993) report that energy and protein content of diet has no influence on plumage condition. However in White Leghorn layers, Ambrosen and Petersen (1997) indicate that protein contents in layer diets especially for light strains should not be below 15.2% as low levels of lysine, methionine and threonine and amino acid imbalances could result in poor plumage condition and high rates of cannibalism. Poor plumage condition, excessively long claws and high incidence of foot damage were found to be associated with feeding low protein diets (Bustany and Elwinger, 1987). During rearing, feathering was improved on high level of cystine (0.43%) while 0.55% methionine and cystine improved feather cover during lay (Perry and Cooke, 1982). High wheat diets were observed to result in inferior plumage owing to feather pecking (Abrahamsson *et al.* 1996).

Changes in feed composition of diets during the production cycle have been followed by increased mortality (Curtis and Marsh, 1992). The feeding of oats, however, has been shown to increase plumage condition and decrease cannibalism (Albustany and Elwinger, 1988).

Plumage cover, feed intake and feed efficiency

Food consumption increases when the plumage cover decreases (Emmans and Charles, 1976; Biedermann *et al.* 1993 and Damme and Pirchner, 1984). Birds at 15^0C with very good plumage ate 118 g/bird while naked birds consumed 159 g/bird. Tauson and Svennson (1980) housed hens at 18^0C and showed well feathered hens consumed 116 g/bird, while hens with poor feather cover consumed 147g/bird. Peguri and Coon (1993) found the feed intake of 59 week-old White Leghorns with no feather cover was 26 g/bird higher than birds with

complete cover. Poor plumage has also been shown to decrease efficiency of feed utilisation (Leeson and Morrison, 1978; O'Neil *et al.* 1971; Tauson and Svensson, 1980; Tullet *et al.* 1980, Raastad and Katle, 1989 and Damme and Pirchner, 1984). Low efficiency hens had poorer plumage on the neck and breast, and the poorer the plumage the more agitation they showed (Raastad and Katle, 1989). In contrast, Hagger *et al.* (1989) reported improved conversion from hens with poor feather cover. Hens with severe feather damage had a reduced body weight after 40 weeks (Damme and Pirchner, 1984) and at end of lay (Conson, 1985).

Plumage cover and production

White Leghorn birds with no feather cover had higher egg weight but egg production was 9.2 and 6.4% lower at 12.8 and 23.9^{0}C respectively compared to hens with full cover. At 33.9^{0}C, however, egg production was 5.5% higher in birds with no feather cover (Peguri and Coon, 1993). The authors state that it is important that feather cover of layers be maintained when hens are housed in cold and thermoneutral temperatures but there are benefits for hens if they have poor feather cover in hot weather.
Biedermann *et al.* (1993) reported that brown layers with intact plumage had reduced mortality, a higher egg production, lower feed consumption and fewer cracked eggs, while Mills *et al.* (1988) found that there was a negative correlation in 52 week old layers between feathering and egg production but a positive correlation between feathering and age at first egg. In contrast, Bessei (1984) found a negative correlation between feather condition and age at first egg. Damme and Pirchner (1984) worked with heavier breeds and found that at peak production there was no effect of defeathering on production. After 40 weeks of age, however, there was a highly significant relationship between feather loss and body weight deterioration but poorly feathered hens showed a higher egg mass output. Charles (1980) reported that poor feather cover can depress production whereas Hagger *et al.* (1989) reported higher egg production from hens with poor feather cover.

Feather cover and welfare

The poor feather cover of older hens in cages has been a key factor contributing toward the welfare groups perceived negative image of the caged layer industry. While older caged hens maintain good health and performance their feather cover deteriorates to a level where considerable body areas are naked. Hens with poor feather cover are also more susceptible to pecking attacks from other hens and also to abrasions. Recent anatomical and behavioural studies by Glatz and Lunam (1996) indicate that welfare of birds with poor feather cover is not compromised. Barnett and Glatz (1995) report that while the cosmetic appearance of the bird is affected when it has poor feather cover it has few implications for their welfare based on physiological variables.

CHAPTER II
FEATHER COVER EXPERIMENT

Introduction

Research findings indicate that food consumption could be 10-30% higher in hens with the most worn plumage. In Australia, a considerable proportion of the national flock are old hens with deteriorating feather cover. During winter (or more particularly when environmental temperatures are below 20^0C) these hens could be consuming millions of dollars of additional feed. These estimates need to be validated under field conditions. It is possible the research work published on increases in food intake associated with poor feather cover may be an over estimate of the situation under commercial conditions. It is therefore essential that an assessment under commercial conditions be made to determine the extent of the influence of poor feather cover on feed intake. If poor plumage condition does substantially influence the hen's feed requirements, information on best practice to minimise feather loss in poultry can be extended to the Industry. The farmer will then be able to determine whether maintaining old hens with poor feather cover is economically viable and whether husbandry strategies to improve feather cover should be practised.

This study was undertaken to evaluate the biological and economic significance of poor feather cover in hens in a commercial poultry house in South Australia during winter. The experiment examined the effect of poor feather cover on production and profitability in two commercial strains of layers (tinted and brown egg) housed at four per cage (600 cm^2/bird) from 91-98 weeks of age. Feather cover was assessed using a 4 point scoring system for individual body parts to obtain an overall feather score.

Materials and Methods

Beak trimming procedure

A person with extensive commercial experience used a Lyon trimming machine to remove one half of the upper beak and one third of the lower beak from chickens at 7 days of age. Only those pullets with excessive regrowth of the beak were retrimmed at 12 weeks of age.

Birds and management

Two strains of layer birds (Tegel Tint and Tegel Brown) were obtained from a commercial pullet grower at 17 weeks of age. From 17-86 weeks birds were involved in a series of trials examining the nutritive value of lupins in layer diets. During the feather cover study (87-98 weeks) hens were fed a mash diet (g/kg) comprising:

Wheat 200; peas 113; triticale 400; lucerne hay 25; meat meal 102; soyabean meal 50; limestone 80; methionine 2; salt 1, canola oil 25; premix of vitamins, trace elements and yolk colourant 2.

Minimum calculated levels of metabolizable energy (ME), crude protein (Nx6.25) and calcium for the layer diet were 11.5 MJ/kg; 17.6% protein and 3.1% calcium.

Previously birds were vaccinated against Marek's disease at hatching, infectious bronchitis at 4 days and again at 4 weeks, avian encephalomyelitis at 10 weeks and fowl pox at 12 weeks. A coccidiostat was provided to the birds via the water during the rearing phase.

The laying phase for this experiment commenced in July 1997 (mid winter) and continued through to September 1997 (early spring). The temperature range in the shed during this period was 13.2-16.8^{0}C. Hens were housed 4 per cage in 192 Harrison 'Welfare' back-to-back, single tier cages (each 500 mm wide by 545 deep; 600 cm^2/bird) in a fan ventilated insulated laying shed with louvred windows. The diet was offered *ad libitum* as mash with free access to water from nipple drinkers. Incandescent lighting was provided in the layer shed and was held constant at 16 h per day. Food was provided to each replicate in custom built feed hoppers. These hoppers could be removed from the cage to enable both easy weighing of food into hoppers and weighing of the food residue. Food was provided to a depth of 2 to 4 cm and total feeding space for each bird at the front of the cage was 12.5 cm. Steel mesh (2.5 x 2.5 cm) was placed over the surface of the feed to reduce the ability of the hen to flick the feed out of the hopper.

Experimental design and analysis

For the experimental phase there were 4 treatments involving 2 feather cover treatments (poor and good feather cover) and 2 strains (Tegel Tint and Tegel Brown). A randomised design was used for allocation of treatments with 22 replicates per treatment. Each replicate comprised 10 birds housed in 2 adjacent cages.

The experiment was analysed using the General Linear Models procedure (using Base-SAS ® software, 1988) for the main factors - feather cover, strain and interactions. Least significant differences were used to separate means when significant main effects ($P<0.05$) were detected by analysis of variance.

Production Measurements

Egg production and mortality were recorded daily, feed intake weekly and egg weight and egg grades were determined on 3 consecutive days every 4 weeks. Financial returns were determined for each treatment.

Plumage condition measurement

At 87 weeks of age all hens were visually assessed for feather cover and allocated to the treatments. At the commencement of the experiment (91 weeks) hens were individually taken out of their cage and examined for feather cover and damage using a scoring system similar to that used by Tauson (1984). The scoring system was a 4 point score applied to the neck, breast, back, wings, vent, tail, base of tail and legs as follows; Score 4: For a part of the body having very good plumage with none or few worn or otherwise deformed feathers; Score 3: For a part of the body where feathers have deteriorated but the skin is still or almost completely covered by feathers; Score 2: For a part of the body that shows very clear deterioration of feathers and or with larger naked areas; Score 1: For a part of the body with heavily damaged feathers with no or only very small areas being covered with feathers. The average feather score for each individual part of the body and an average score for each hen was calculated.

Animal Ethics

The animal ethics committees of the Department of Primary Industries and Resources South Australia and University of Adelaide approved these studies. All procedures complied with the "Australian Code of Practice for the Care and Use of Animals for Scientific Purposes" (Australian Agricultural Council, 1990) and the "Australian Model Code of Practice for the Welfare of Animals. Domestic Poultry" (Standing Committee on Agriculture and Resource Management, 1995).

Results

Feather cover of hens

Overall feather cover of hens from the four treatments was significantly different ($P<0.05$) both at the commencement and conclusion of the experiment (Table 1, Fig 1 & 2). Feather cover of body areas at 91 weeks (Table 3) was also different ($P<0.05$) between the treatments. The body parts with the poorest feather cover were the tail and base of tail for the Tegel Tint, and the base of tail and vent for the Tegel Brown (Table 3). The hens with poor feather cover at the commencement of the trial showed an improvement in feather score by the end of the experiment. In contrast, the hens with good feather cover at the start of the trial showed a deterioration in feather score by the end of the experiment (Table 1).

Correlations

There was a significant negative correlation ($P<0.05$) between feed intake (from 91-98 weeks) and feather score at 91 weeks (Table 2). Feather score on back and neck showed the highest correlation ($r = -0.85$) with food intake (Table 2). The back and the vent were the best indicators of overall feather score (Table 4). The tail and base of tail were the body parts most affected in birds with poor feather cover.

Production

Liveweight of hens from the four treatments was significantly different ($P<0.05$) both at the commencement and conclusion of the experiment (Table 1, Fig 3 & 4). Birds with poor feather cover had higher ($P<0.05$) food intake (Table 5 & Fig 5) than birds with good feather cover (Table 5). Egg production (Table 6 & Fig 6) was lower ($P<0.05$) for birds with poor feather cover in the first week of the trial and remained consistently lower throughout the experiment (Table 6 & Fig 6). There was a trend for birds with poor feather cover to produce heavier ($P=0.08$, Table 7 & Fig 7) but poorer ($P<0.05$) FCE than hens with good feather cover (Table 8 & Fig 8). Hens with poor feather cover tended to produce more ($P=0.09$) oversized eggs (Table 9 & Fig 9), fewer ($P=0.09$) extra large eggs (Table 9 & Fig 10) and less ($P=0.11$) egg income (Table 10 & Fig 11) than birds with good feather over the period 91-98 weeks. There were no biologically important 2 or 3 way interactions observed in the analyses.

Table 1. Feather score and liveweight at 91 & 98 weeks for hens with poor and good feather cover.

Treatment	Feather score at 91 weeks	Feather score at 98 weeks	Liveweight at 91 weeks kg	Liveweight at 98 weeks kg
Poor Tinted	2.1768c	2.2835b	2.0707c	2.1488c
Good Tinted	2.7607a	2.5741a	2.161 b	2.2019bc
Poor Brown Egg	1.4798d	1.6249d	2.1526b	2.2513b
Good Brown Egg	2.3743b	2.0803c	2.3321a	2.3904a
l.s.d. (P=0.05)	0.121	0.157	0.064	0.086

(Means within columns followed by the same letter are not significantly different at P=0.05, l.s.d.=least significant difference)

Table 2. Simple correlation coefficients (r) of feather score at 91 weeks with feed intake

Feed intake (weeks)	Neck	Breast	Back	Tail	Base of tail	Vent	Legs	Wing	Overall Score
91	-0.73	-0.75	-0.74	-0.62	-0.67	-0.70	-0.72	-0.71	-0.76
92	-0.69	-0.72	-0.74	-0.56	-0.64	-0.68	-0.74	-0.69	-0.75
93	-0.74	-0.74	-0.77	-0.68	-0.74	-0.75	-0.72	-0.75	-0.81
94	-0.77	-0.71	-0.77	-0.65	-0.70	-0.67	-0.70	-0.75	-0.78
95	-0.72	-0.66	-0.70	-0.58	-0.65	-0.66	-0.65	-0.65	-0.71
96	-0.73	-0.68	-0.73	-0.66	-0.71	-0.70	-0.63	-0.71	-0.76
97	-0.74	-0.66	-0.75	-0.65	-0.72	-0.69	-0.59	-0.72	-0.76
98	-0.74	-0.66	-0.74	-0.65	-0.71	-0.68	-0.60	-0.71	-0.75
Ave (91-98)	-0.73	-0.70	-0.74	-0.63	-0.70	-0.70	-0.68	-0.71	-0.76

Table 3. Feather score of body parts at 91 weeks for hens with poor and good feather cover.

Treatment	Neck	Breast	Back	Tail	Base of tail	Vent	Legs	Wings	Overall Score
Poor Tinted	2.156b	2.016b	2.320b	1.625c	1.883c	2.039c	2.805b	2.570b	2.1768bc
Good Tinted	2.578a	2.359a	2.953a	2.414a	2.969a	2.828a	3.046a	2.937a	2.7607a
Poor Brown	1.479c	1.521c	1.469c	1.719d	1.141d	1.417d	2.073c	1.568d	1.479d
Good Brown	2.141b	2.223a	2.386b	2.109b	2.125b	2.582b	3.087a	2.342c	2.374b
l.s.d.(P=0.05)	0.151	0.151	0.182	0.184	0.212	0.230	0.198	0.169	0.121

(Means within columns followed by the same letter are not significantly different at P=0.05, l.s.d.=least significant difference)

Table 4. Simple correlation coefficients (r) between body parts for feather score

Body part	Neck	Breast	Back	Tail	Base of tail	Vent	Legs	Wing	Overall Score
Neck		0.525	0.589	0.499	0.451	0.534	0.477	0.581	0.716
Breast			0.562	0.554	0.463	0.658	0.604	0.513	0.753
Back				0.606	0.745	0.639	0.585	0.639	0.852
Tail					0.675	0.681	0.493	0.573	0.809
Base of tail						0.607	0.496	0.559	0.812
Vent							0.648	0.549	0.850
Legs								0.511	0.758
Wings									0.770

Table 5. Effect of feather cover and strain on feed intake (g/bird/day)

	Weeks of age								
Treatment	91	92	93	94	95	96	97	98	Ave
Feather Cover									
Good	111.5a	117.1a	115.6a	115.4a	118.5a	113.5a	114.7a	116.8a	115.4a
Poor	131.3b	137.2b	134.8b	133.6b	135.8b	132.8b	133.1b	128.6b	133.4b
l.s.d.	4.2	5.4	4.4	4.7	5.4	4.9	4.3	6.9	3.4
Strain									
Brown	128.2a	135.5a	133.6a	133.0a	134.8a	130.4a	131.5a	128.7a	131.9a
Tint	111.7b	115.1b	113.1b	112.2b	116.0b	112.7b	113.0b	114.1b	113.5b
l.s.d.	4.3	5.5	4.4	4.8	5.5	4.9	4.4	7.0	3.5

(Means within columns within comparison followed by the same letter are not significantly different at P=0.05, l.s.d. =least significant difference, ns=not significant)

Table 6. Effects of feather cover and strain on egg production (%)

	Weeks of age								
Treatment	91	92	93	94	95	96	97	98	Ave
Feather cover									
Good	44.4a	41.1	38.6	36.5	37.2	34.6	33..2	33.8	37.4
Poor	39.2b	37.3	36.7	35.8	32.4	31.7	30.9	33.1	34.6
l.s.d.	5.0	ns	ns	ns	ns	ns	ns	ns	ns
Strain									
Brown	40.9	40.3	38.2	37.2	36.0	33.1	32.1	33.6	36.4
Tint	42.8	37.4	36.8	34.6	32.9	33.1	31.9	33.2	35.3
l.s.d.	ns	ns	ns	ns	ns	ns	ns	ns	ns

(Means within columns within comparison followed by the same letter are not significantly different at P=0.05, l.s.d.=least significant difference, ns=not significant)

Table 7. Effect of feather cover and strain on egg weight (g)

	Weeks of age								
Treatment	91	92	93	94	95	96	97	98	Ave
Feather cover									
Good	67.5	68.6	68.1	69.2	69.4	68.6	69.5	68.7	68.6
Poor	67.9	68.9	69.1	69.7	69.8	67.8	69.8	69.1	68.9
l.s.d.	ns	ns	ns	ns	ns	ns	ns	ns	ns
Strain									
Brown	67.5	68.4	68.7	68.9	68.6	68.3	69.4	69.7	68.4
Tint	67.9	69.3	68.4	70.2	69.9	69.5	69.9	69.8	69.2
l.s.d.	ns	ns	ns	ns	ns	ns	ns	ns	ns

(l.s.d.=least significant difference, ns=not significant)

Table 8. Effect of feather cover and strain on FCE (kg/dozen eggs)

	Weeks of age								
Treatment	91	92	93	94	95	96	97	98	Ave
Feather cover									
Good	3.3a	3.8a	3.9a	4.3	4.3a	4.5a	4.5a	4.7	4.0a
Poor	4.3b	4.9b	5.2b	5.2	6.5b	5.8b	6.5b	5.6	5.1b
l.s.d.	0.7	0.8	1.0	ns	1.9	1.2	1.7	ns	0.8
Strain									
Brown	4.2a	4.6	5.0a	5.1	5.8	5.7a	6.3a	5.7a	4.9a
Tint	3.3b	4.0	3.9b	4.2	4.8	4.4b	4.5b	4.4b	4.0b
l.s.d.	0.7	ns	1.0	ns	ns	1.2	1.7	1.1	0.8

(Means within columns within comparisons followed by the same letter are not significantly different at P=0.05, l.s.d.=least significant difference, ns=not significant)

Table 9. Effect of plumage condition and strain on percentage of egg grades and income for hens 91-98 weeks of age

Treatment	Oversized	Extra Large	Large	Medium	Commercial	Egg Income
Feather Cover						
Good	36.9	18.7	4.3	0.3	0.2	$1.86
Poor	40.4	15.0	5.0	0.3	0.4	$1.71
l.s.d.	ns	ns	ns	ns	ns	ns
Strain						
Brown	38.6	17.6	4.5	0.4	0.5	$1.82
Tint	38.8	15.6	4.9	0.1	0.1	$1.74
l.s.d.	ns	ns	ns	ns	ns	ns

(l.s.d., ns =not significant)

Table 10. Effect of plumage condition and strain on percentage of second quality eggs for hens 91-98 weeks of age

Treatment	No value	Seconds	Waste	Dirty
Feather Cover				
Good	5.5	32.9	0.9	7.6
Poor	6.3	31.5	1.1	6.7
l.s.d.	ns	ns	ns	ns
Strain				
Brown	6.1	31.2	1.1	7.3
Tint	6.0	33.7	0.8	7.0
l.s.d.	ns	ns	ns	ns

(l.s.d.=least significant difference, ns=not significant)

Fig 1. Feather score at 91 weeks for hens with poor and good feather cover. Error bar is l.s.d.

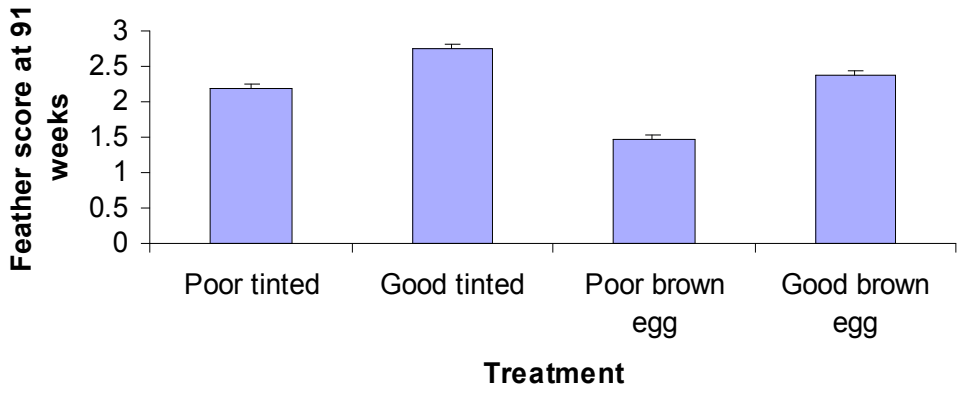


Fig 2. Feather score at 98 weeks for hens with poor and good feather cover. Error bar is l.s.d.

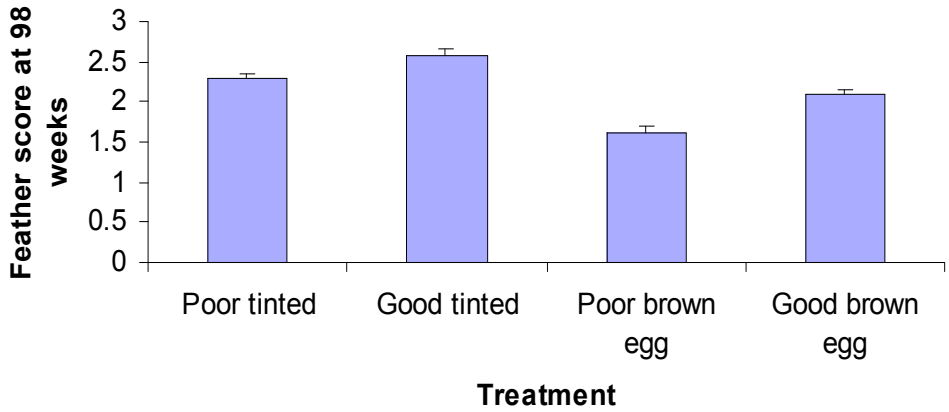


Fig 3. Liveweight at 91 weeks for hens with poor and good feather cover.
Error bar is l.s.d.

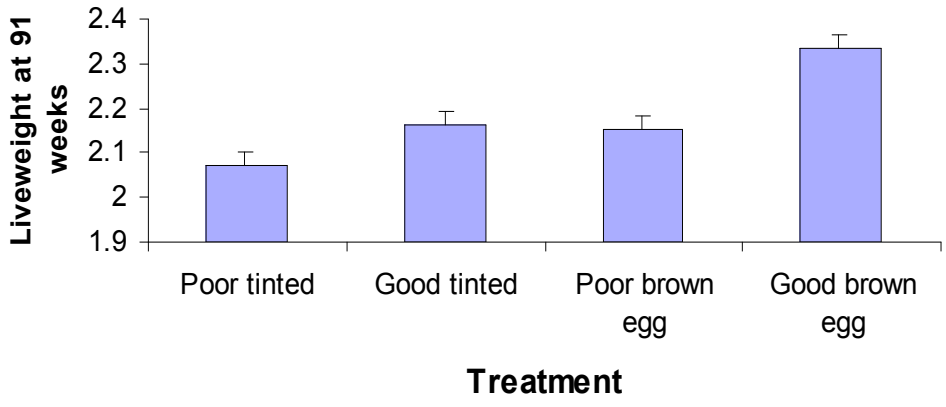


Fig 4. Liveweight at 98 weeks for hens with poor and good feather cover
Error bar is l.s.d.

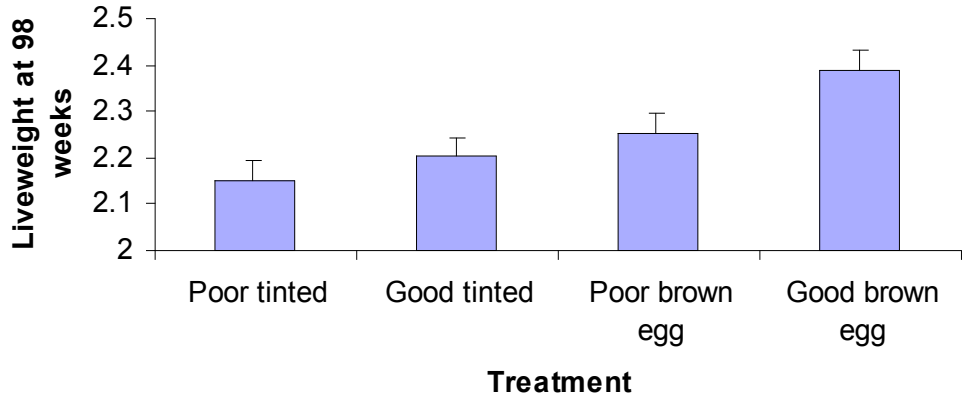


Figure 5. Feed intake of hens with good and poor feather cover.
Error bar is l.s.d.

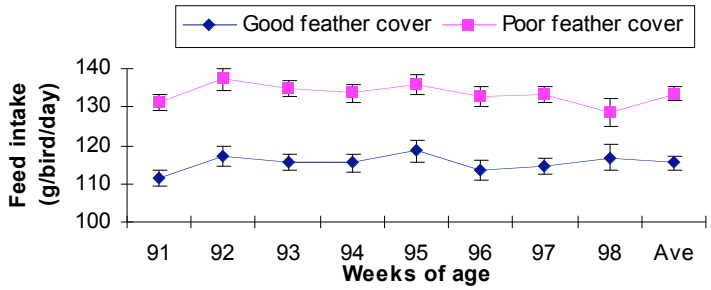


Figure 6. Effects of feather cover on egg production.
Error bar is l.s.d.

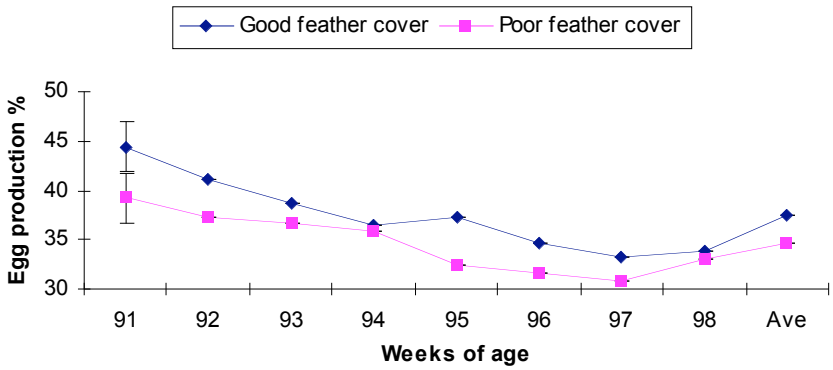
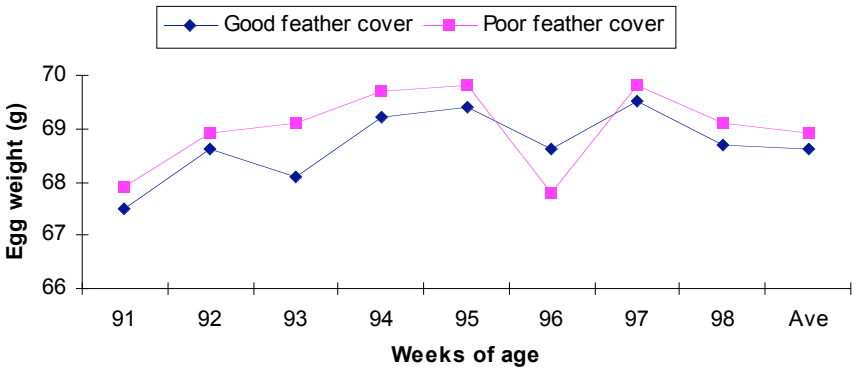


Figure 7. Effect of feather cover on egg weight



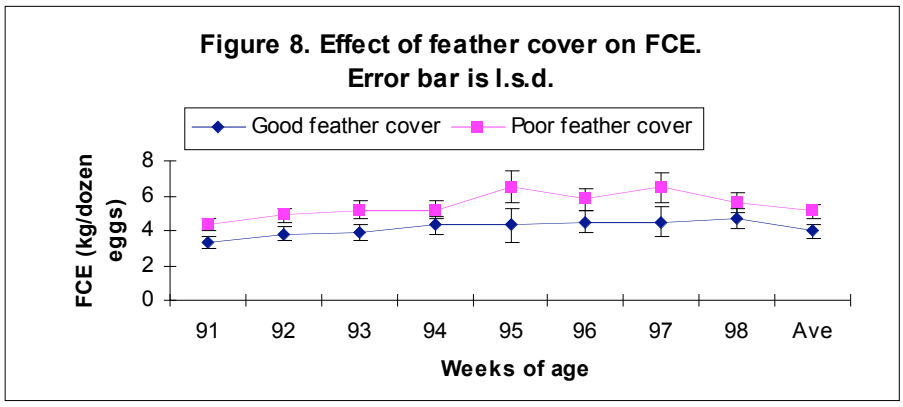


Figure 8. Effect of feather cover on FCE.
Error bar is l.s.d.
Good feather cover
Poor feather cover
FCE (kg/dozen eggs)
8
6
4
2
0
91
92
93
94
95
96
97
98
Ave
Weeks of age

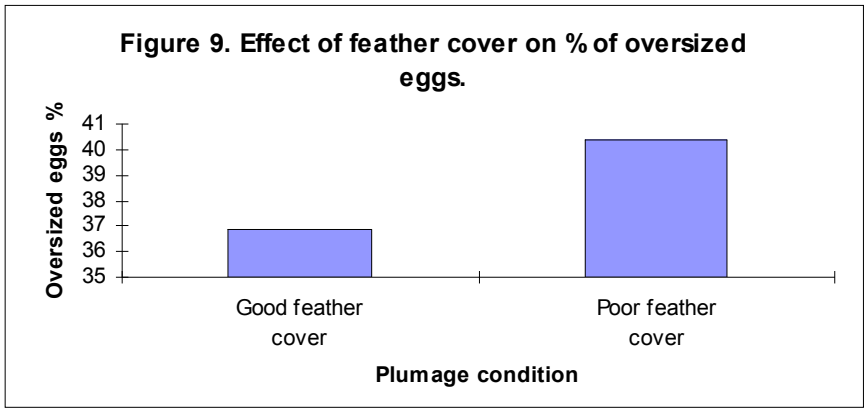


Figure 9. Effect of feather cover on % of oversized eggs.
Oversized eggs %
41
40
39
38
37
36
35
Good feather cover
Poor feather cover
Plumage condition

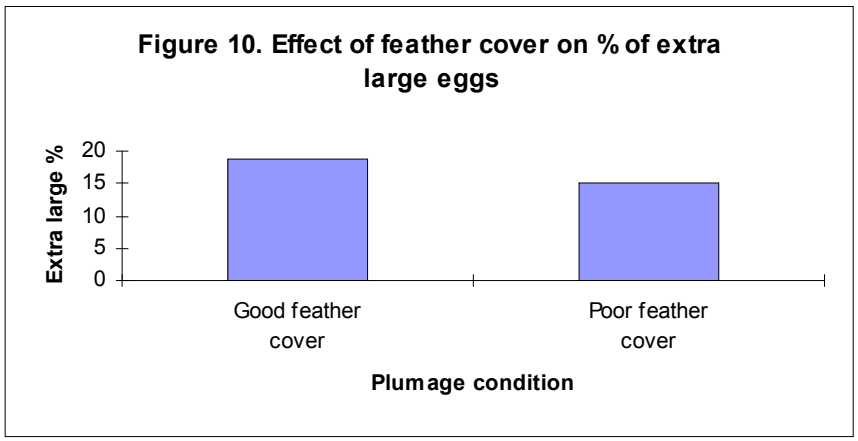


Figure 10. Effect of feather cover on % of extra large eggs
Extra large %
20
15
10
5
0
Good feather cover
Poor feather cover
Plumage condition

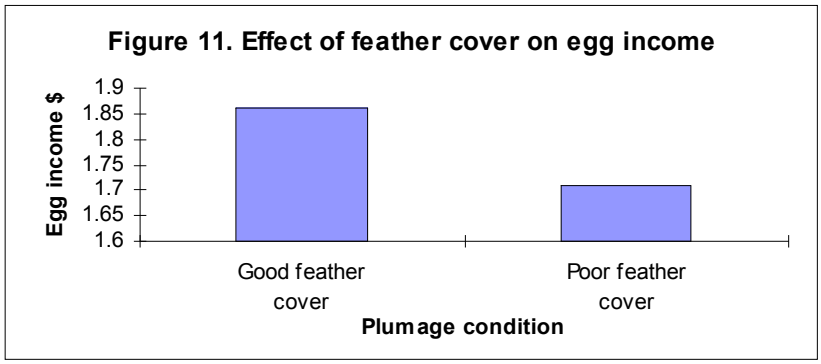


Figure 11. Effect of feather cover on egg income
Egg income $
1.9
1.85
1.8
1.75
1.7
1.65
1.6
Good feather cover
Poor feather cover
Plumage condition

Discussion

Feed intake and production

At the end of lay, 50% of hens in our trial were classified as having poor feather cover. In general the deterioration in feather cover begins to occur soon after the hens are caged. When the hens reach 40 weeks of age a considerable proportion of the birds have significant feather wear and bare patches. It is well known that many birds show a steady decline in feather cover (Tauson, 1986). During winter, and even during cool nights in summer, this can cause a large increase in feed intake.

In this current trial where environmental temperatures ranged from 13.2-16.8^{0}C, the increase in feed intake attributable to poor feather cover was 18 g/bird/day. Overseas research reports (Tauson and Svenson, 1980; Perguri and Coon, 1993) indicate that naked birds consume an extra 26-31g/bird at the equivalent temperatures that were used in our study. About 5% of the hens in our trial were completely naked. The results show that farmers can suffer considerable increases in feed costs and losses in egg income because of poor feather cover of hens. If the assumption is made that half of the Australian hen flock have poor feather cover and are subject to environmental temperatures below 20^{0}C for 50% of the time they are housed, then increases in food costs amounts to $6.57m annually. This figure is calculated from the extra 18g food consumed per bird/day priced at $400/tonne. On the basis of results obtained in our study, loss in egg income is estimated to be 8% over the same period which amounts to $1.50/bird or $7.5m annually. This is calculated from an estimated production of 12.5 dozen @ $1.50/dozen.

In this current trial birds which had poor feather cover had lower egg production which agrees with most reports from the literature (Perguri and Coon, 1993; Biedermann *et al.* 1993, Charles 1980). The exception to this is when birds are at peak of lay (Damme and Pirchner, 1984) or exposed to high environmental temperature (Perguri and Coon, 1993). Feed conversion efficiency was inferior because of poor feather cover which supports the findings already reported in the literature. Raasted and Katle (1989) indicated that birds with poor plumage on the neck and breast had poor food conversion efficiency. Our results suggest that poor feather cover on the neck and back contributes more to high food intake in hens and subsequently poorer feed conversion efficiency. The back is more exposed to the environment than the breast and a naked back with the larger surface area might be expected to have a greater heat loss than the breast. Body weight of hens with poor feather cover was lower supporting the previous findings of Damme and Pirchner (1984) and Conson (1985). There was a trend for the hens with poorer feather cover to produce more oversized eggs relative to the extra large eggs, presumably because of their higher food intake.

Influence of diet

In Europe, Isa Brown and Lohman laying strains which had 50% wheat in their diet had poorer feather cover than birds on a 25% wheat diet (Abrahamsson *et al*. 1996). The inferior plumage condition was caused by feather pecking. Large proportions of wheat in diets is not recommended in Sweden.
In line with these observations, work in horses revealed that as the levels of grain in the diet increased there was an increase in frequency of stereotype behaviours (wood chewing,

licking) coinciding with the development of lactic acidosis or acidic gut syndrome. The syndrome which is associated with a decrease in faecal pH is characterised by behavioural changes, increased risk of gut infections, skin and respiratory conditions. A potential high risk factor leading to the development of acidic gut syndrome in layers could be the consumption of low ME wheats containing high levels of non starch polysaccharides (NSP). Reduced faecal pH's in poultry have been associated with high NSP diets. In this project birds were consuming a wheat triticale based diet with potentially high levels of NSP which could have contributed to an acidosis problem in the hen resulting in increased feather pecking and poor feather cover of the flock.

Effect of long claws

It is clear from our studies that there is a close relationship between feather cover and food intake. Poultry farmers should monitor feather cover regularly and those birds with considerable feather loss on the back and neck consume most food. Strategies to improve feather cover on the back include reducing the incidence of dust bathing in cages which can be stimulated by dusty feeds. Likewise some birds do scratch the feathers from the backs of birds with their claws. This could be prevented by installing abrasive strips on the egg guard (Tauson, 1986).

Bird's claws grow continuously and cage floors do not allow for the on-going wearing down that occurs in floor housed birds. With long claws, birds can injure themselves and cage mates and run the risk of getting trapped in the cage structure. Long twisted claws are frequently quoted as a negative aspect of caging. Tauson (1986) reported a low-cost, non-invasive method by which the claws of caged layers could be kept short and blunt through the laying year. He recommended sticking an 8 mm strip of abrasive tape on the egg guard. Bird's claws scraped against this tape while they where feeding. This technique offers positive welfare advantages for bird and removes a criticism of cages. Many cages in Australia do not have egg guards and the abrasive strips would need to be fitted to the feed trough.

Declawing birds at the chick stage may also be an option to reduce the feather loss of hens caused by long claws. Many birds do suffer cuts and nicks from claw damage and the use of declawing should perhaps be used as a husbandry practice to reduce cannibalism and feather loss.

Use of sprays to reduce feather pecking

For many years poultry farmers have been using antiseptic coloured sprays to treat pullets and hens suffering from injuries caused by cannibalism, scratches and abrasions. There is evidence that these stock wound sprays prevent further aggressive feather pecks from other hens and feathers begin to grow back in the sprayed area (R. Bishop personal communication). More extensive use could be made sprays on poorly feathered birds especially late in lay to prevent further feather pecking and improve feather cover.

Rearing Conditions

Early rearing conditions and type of litter has a substantial influence on subsequent feather pecking of hens. Housing conditions that promote foraging behaviour are effective in reducing pecking (Hubereicher and Wechsler, 1997; Blockhuis and Van Der Haar, 1989). Increasing the incentive value of the ground by using straw or grain for floor reared pullets significantly reduced feather damage in the laying period (Blockhuis and Van Der Haar, 1992). These findings are at variance with the report of Sanotra et al. (1995) who report there is a high risk for development of a pathological feather pecking condition when straw or wood shavings are used as litter. Grain has been used to direct foraging-related behaviours like scratching and pecking to the ground ultimately resulting in less feather pecking in the adult phase. Rearing on litter causes hens to feather peck less than hens reared on wire floors (Blockhuis and Van Der Haar, 1992).

Beak trimming

In our studies there was no indication that poor beak trimming was causing an increase in feather pecking. Beak trimming not only reduces the amount but also the effectiveness of feather pecking resulting in a lower degree of feather deterioration (Hughes and Michie, 1982). Flocks inadequately trimmed generally have higher mortality from peck-outs and cannibalism because hens are able to inflict more damage with their beaks. Age of beak trimming can influence the amount of feather pecking (Glatz, 1993). Birds trimmed at hatch do less feather pecking in the adult stage than birds trimmed at 10 days of age.

Light intensity

It is well known in industry that reducing light intensity reduces the need to beak trim poultry as is the case in many European countries. Visitors from Europe have questioned the need to beak trim commercial poultry in Australia. However light intensity is very low in their shedding, and very high in our sheds. In recent years the Europeans have found that their supposedly docile strains when housed outdoors in alternative systems develop severe cannibalism problems necessitating the need to beak trim. Increases in light intensity in the field results in an increase in feather pecking. The relationship between feather cover and light intensity has not been defined in the literature. In our study light intensity was normally 10 lux and raised to 75 lux during egg collection, feeding and weighing of hens.

Relocation of hens with poor feather cover

Our studies have shown that hens with poor feather which were housed together showed an improvement in feather cover. It is recommended that as farmers undertake their daily bird checks, they remove birds with poor feather cover and place them in separate cages. Feather cover of these birds will improve and reduce feeding costs. Some poultry workers make the mistake of culling poorly feathered birds without checking whether they are producing eggs.

Heating sheds

Farmers may be able to employ other strategies to minimise the influence of poor feather cover on food intake. The first is to heat sheds (which have adequate insulation) in winter. For this strategy to be viable the heating costs would have to be lower than the expected increase in feeding costs because of poor feather cover. Alternatively young birds with good feather cover

could be housed in winter to take advantage of the deteriorating feather cover in summer which will be an advantage for hens subject to hot weather.

Implications

The results of our trial show that farmers can suffer considerable increases in feed costs and losses in egg income because of poor feather cover of hens in winter. If the assumption is made that half of the Australian layer flock has poor feather cover and are subject to environmental temperatures below 20^0C for 50% of the time they are housed, then increases in food costs amounts to $6.57m annually. This is based on the extra food intake of 18g/bird/day with feed priced at $400/tonne. On the basis of results obtained in our study, the loss in egg income is estimated to be 8% over the same period which amounts to $1.50/bird (ie. 8% of 12.5 dozen eggs @ $1.50/doz) or $7.5m annually. Total losses to the Egg Industry because of poor feather cover could be in excess of $14m annually.

Recommendations

Practical solutions for the poultry farmer to improve feather cover of hens

- Australian egg farmers should monitor feather cover of layers in their sheds and attempt to raise shed environmental temperatures to 23^0C in winter to avoid the huge increases in food costs (16%) associated with poor feather cover. To raise shed temperatures in naturally ventilated sheds in winter, side panels and ridge vent on sheds should be adjusted to provide recommended ventilation and curtains used to prevent drafts and to retain some of the bird heat. Where possible insulation should be installed to prevent heat loss from the building.

- Less expensive methods that would assist in improving feather cover are to reduce light intensity in layer house, install abrasive strips on egg guard or back of feed trough, fit environment enrichment devices in cages, beak trim early, ensure retrimmed pullets have a 3-4 mm gap between top and bottom beak to reduce effectiveness of pecking and buy pullets that have been reared on the floor. The practise of declawing of layers may need to be reintroduced to prevent the loss of back feathers that occur when birds are trampled

- More expensive options to improve feather cover are to install cages with solid sides (only in controlled environment housing) and horizontal wires at front of cage.

- Producers may also consider housing younger hens with good feather cover in winter. During summer these hens will have poorer feather cover which may increase their ability to cope with hot weather.

- Producers should ensure protein contents in layer diets especially for light strains is not below 15.2% as low levels of lysine, methionine and threonine and amino acid imbalances could cause a deterioration in plumage condition.

- As feather cover problems develop in a flock it is recommended that hens with poor feather cover be placed together to improve their cover and decrease feeding costs.

Further on farm demonstration research is required

- On farm demonstration trials are required to determine which of the following simple husbandry practices are the most effective in improving feather cover.

- It is suggested that feather cover of hens on egg farms be compared under the following rearing treatments:

  → pullets reared on floor versus cages
  → chicks reared on sand versus sawdust
  → pullets reared on sand versus litter
  → pullets fed scratch grain or provide straw versus control
  → abrasive strips and enrichment devices in rearing cages versus control
  → early versus late beak trimming
  → standard retrimming versus 4 mm gap between upper and lower beak
  → declawed versus not declawed

- In the laying phase it is suggested that feather cover of hens on farms be compared where the following cage devices have been fitted.

    → abrasive strips on egg guard or feed trough versus control
    → environmental enrichment devices versus control

- It is recommended that a cost benefit analysis be conducted to determine if heating sheds (that have adequate insulation) to 23^0C in winter is feasible compared with the extra feeding costs associated with poor feather cover.

- Basic studies are required to determine the influence of the preening gland on feather cover. Observations indicate that birds with poor feather cover may have a non functional uropygial gland. The feathers of these birds appear to be devoid of oil, making them dry and brittle and perhaps easier for other birds to grasp and remove. Nutritional, physiological, environmental and husbandry factors could be responsible for uropygial gland dysfunction and subsequent poor feather cover.

References

Ambrosen T and VE Petersen (1997). The influence of protein level in the diet on cannibalism and quality of plumage in layers. *Poult Sci* **76** (4): 559-563

Agricultural and Resource Management Council of Australia and New Zealand; Animal Health Committee. (1995). *Australian Model Code of Practice for the Welfare of Animals. Domestic Poultry.* CSIRO, Melbourne

Abrahamsson P, R Tauson R and K Elwinger (1996). Effects on production, health and egg quality of varying proportions of wheat and barley in diets for two hybrids of laying hens kept in different housing systems. *Acta Agric Scand An Sci* **46**: 173-182

Bustany ZA and K Elwinger (1988). Whole grain, unprocessed rapeseed and beta-glucanase in diets for laying hens. *Swed J Agric Res* **18**: 31-40

Bustany ZA and K Elwinger (1987). Response of laying hens to different dietary lysine intakes: A comparison of some commercial hybrids with strains selected on a low protein diet. *Acta Agric Scandinavica* **37** (2): 27-40

Barnett JL and PC Glatz (1995). Welfare and productivity of laying hens in modified cages. A final report submitted to the Egg Industry Research and Development Council

Bessei W (1984). Genetic relations between performance, feathering and fear in laying hens. *Archiv Fuer Gefluegelkunde* **48** (6): 231-239

Biedermann G, N Schmiemann and K Lange (1993). Investigation of the influence of the condition of the plumage of layers in different ages. *Archiv fur Geflugelkunde* **57** (6): 280-285.

Blockhuis HJ (1986). Feather pecking in poultry: its relation to with ground pecking. *App An Behav Sci* **16**: 63-67

Blockhuis HJ (1989). The effect of a sudden change in floor type on pecking behaviour in chicks. *App An Behav Sci* **22**: 65-73

Blockhuis HJ (1992). Effects of pecking incentives during rearing on feather pecking of laying hens. *Br Poult Sci* **33**: 17-24

Charles DR (1980). Environment for poultry. *Vet Record* **106**(14): 307-309

Conson M (1985). Study of a method fro evaluating the plumage of laying hens when the animal material at hand is of varying origin and has been structured by various treatment. *Arbeitin Aus Dem Institut Fuer Tierzuchtwissenschwaft der Rheinischen Friedrich-Wilhekms-Universitaet Bonn* **0** (70):I-III, 1-27

Craig JV and WM Muir (1996). Group selection for adaptation to multiple-hencages-beak related mortality, feathering, and body weight responses. *Poult Sci* **75** (3): 294-302.

Curtis PE and NWA Marsh (1992). Cannibalism in laying hens. *Vet Record* **131** (14): 424-427

Damme K and F Pirchner (1984). Genetic differences of feather-loss in layers and effects on production traits. *Archiv fuer Gefluegelkunde* **48** (6): 215-222

Damme K, F Pirchner, H Willeke and H Eichinger (1987). Fasting metabolic rate in hens: 1. Effects of body weight, feather loss, and activity. *Poult Sci* **66** (5): 881-890

Emmans GC and DR Charles (1976). Climatic environment and poultry feeding in practice. Proc 10th Nutr Conf Fd Mfrs., Univ of Nottingham.

Freeman BM (1971). Body temperature and thermoregulation. In "*Physiology and Biochemistry of the Domestic Fowl"*, Ed. DJ Bell and BM Freeman; Academic Press, London and New York.

Glatz PC (1993). When is the best age to beak trim chickens. Final report to Egg Industry Research and Development Corporation.

Glatz PC and CA Lunam (1996). Behavioural and anatomical aspects of poor feather cover in caged hens. *Proc of Aust Poult Sci Symp* **8**: 157-160

Glatz PC and JL Barnett (1996). Effect of perches and solid sides on production, plumage and foot condition of laying hens housed in conventional cages in a naturally ventilated shed. *Aust J Exp Ag* **36**: 269-275

Hagger C, Marguerat C, D Steiger-Stafl and G Stranzinger (1989). Plumage condition, feed consumption, and egg production relationships in laying hens. *Poult Sci* **68**: 221-225

Herremans M, AA El-Azim, P Merat and E Decuypere. Some physiological, morphological and production parameters associated with the naked neck gene (Na) in dwarf (dw) laying hens. *Archiv fuer Gefluegelkunde* **52** (5): 181-187

Hester PY, WM Muir, JV Craig and JL Albright (1996). Group selection for adaptation to multiple-hen-cages-production traits during heat and cold exposure. *Poult Sci* **75** (11): 1308-1314.

Hubereicher B and B Wechsler (1997). Feather pecking in domestic chicks-its relation to dustbathing and foraging. *An Behav* 54 (4): 757-768

Hughes BO and W Michie (1982). Plumage loss in medium bodied hybrid-hens: The effect of beak trimming and cage design. *Br Poult Sci* **23**: 59-64

Johnson RJ and DJ Farrell (1983). Energy metabolism of groups of broiler breeders in open-circuit respiration chambers. *Br Poult Sc* **24**: 439-453

Kostal L, Savory CJ and BO Hughes (1992). Diurnal and individual variation in behaviour of restricted fed broiler breeders. *App An Beh Sci* **32**: 361-374

Kjaer JB and P Sorensen (1997). Feather pecking behaviour in White Leghorns, a genetic study. *Br Poult Sci* **38** (4): 333-341.

Leeson S and WD Morrison (1978). Effects of feather cover on feed efficiency in laying birds. *Poult Sci* **57**: 1094-1096

Leonard ML, Horn AG and RW Fairfull (1995). Correlates and consequences of allopecking in White Leghorn Chickens. *App An Beh Sci* **43** (1): 17-26.

Lindberg AC and CJ Nicol (1994). An evaluation of the effect of operant feeders on welfare of hens maintained on litter. *App An Beh Sci* **41** (3-4): 211-227.

Merat P, A Bordas and G Coquerelle (1979). The relationship of several genes suppressing plumage colour with body weight, food intake and feather loss of laying hens. *Br Poult Sci* **20** (6): 587-594

Mills AD, JM Faure and JB Williams (1988). Feather loss and egg production in broiler breeders and layers. *Ann de Zootech* **37** (3): 133-142

Mitchell MA (1985). Measurement of forced convective heat transfer in birds: a wind tunnel calorimeter. *J Therm Biol* **10** (2): 87-96

Nichelman M, E Baranyiova, R Goll and B Tzschentke (1986). Influence of feather cover on heat balance in laying hens (*Gallus Domesticus*). *J Therm Biol* **11** (2): 121-126

The National Health and Medical Research Council, Code Liaison Group. (1985). *The Australian Code of Practice for the Care and Use of Animals for Scientific Purposes.* Australian Government Publishing Service, Canberra

Norgaardnielsen G (1997). Dustbathing and feather pecking in domestic chickens reared with and without access to sand. *App Anim Beh Sci* **52** (1-2): 99-108.

O'Neil SJB, D Balnave and N Jackson (1971). The influence of feathering and environmental temperature on the heat production and efficiency of utilisation of metabolizable energy by the mature cockerel. *J Agric Sci Camb* **77**: 293-305

Perry GC and BC Cooke (1982). Effect of cystine in the diet on feathering in pullets and laying hens. *Avicolt* **51** (11): 31-34

Peguri A and C Coon (1993). Effect of feather coverage and temperature on layer performance. *Poult Sci* **72** (7): 1318-1329

Raastad BO and J Katle (1989). Behavioural differences between laying hen populations selected for high and low efficiency of food utilisation. *Br Poult Sci* **30** (3): 533-544

Statistical Analyses Systems Inc. (1988). SAS procedures guide, Release 6.03 Edition. Cary, North Carolina, USA.

Sanotra GS, KS Vestergaard, JF Agger and LG Lawson (1995). The relative preference for feathers, straw, wood-shavings and sand for dust bathing, pecking and scratching in domestic chicks. *App An Beh Sci* **43** (4): 263-277

Savory CJ and JS Mann (1997). Behavioural development in groups of pen-housed pullets in relation to genetic strain, age and food form. *Br Poult Sci* **38** (1): 38-47

Tauson R (1984). Plumage condition in SCWL laying hens kept in conventional cages of different designs. *Acta Agricult Scand* **34**: 221-230

Tauson R and SA Svensson (1980). Influence of plumage condition on the hen's feed requirement. *Swed J Agric Res* **10**: 35-39

Tullet SG, MG Macleod and TR Jewitt (1980). The effects of partial defeathering on energy metabolism in the laying fowl. *Br Poult Sci* **21**: 241-245

Vestergaard KS, Kruijt JP and JA Hogan (1993). Feather pecking and its relation to dustbathing in the Red Junglefowl. Proceedings of the Fourth European Symposium on Poultry Welfare. Edinburgh, pp 242-243

Communications Strategy

The findings from this study will be communicated to Industry as follows:

- Report of key findings and recommendations were published in Autumn 1998 issue of in "In an Egg Shell". This newsletter is mailed to all sectors of the commercial Egg Industry in Australia.

- There will be a seminar presentation of the results of the study to South Australian egg producers at 1998 SA Pig and Poultry Fair in July 1998

It is also proposed to present the results of this study at the following conferences:

- 1999 Poultry Science Symposium in Sydney
- 1999 Australasian Stockfeed convention in Queensland

Findings will also be communicated in:

- Refereed scientific journals
- Poultry magazines
- Fact sheets for egg industry
- Presentations at regional egg producer meetings