RURAL INDUSTRIES RESEARCH
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Egg Program

Production and Welfare of Layers Housed At High and Low Stocking Density in Modified Existing Cage Units

A report for the Rural Industries Research and Development Corporation

By

Geoff Stewart

April 1999
RIRDC Publication No:

ISBN *(RIRDC to allocate)*
ISSN 1440-6845

"Production and Welfare of Layers Housed At High and Low Stocking Density in Modified Existing Cage Units"
Publication no …….
Project no. UQ-23E

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Researcher Contact Details

Name	Mr Geoff Stewart
Address	Dept of Primary Industries – Intensive Livestock Environmental Management Services PO Box 102 Toowoomba, QLD 4350
Phone:	(07) 4688 1125
Fax:	(07) 4688 1192
Email:	E-Mail: stewargd@dpi.qld.gov.au
Website:	

RIRDC Contact Details

Rural Industries Research and Development Corporation
Level 1, AMA House
42 Macquarie Street
BARTON ACT 2600
PO Box 4776
KINGSTON ACT 2604

Phone:	02 6272 4539
Fax:	02 6272 5877
Email:	rirdc@netinfo.com.au
Website:	http://www.rirdc.gov.au

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PROJECT DETAILS:

Project No.	**UQ-23E**
Project title	**The production and welfare of layers housed at high and low stocking density in modified existing cage units.**
Location	**School of Veterinary Science and Animal Production, University of Queensland, Gatton College**
Supervisor	**Dr.J.G.Dingle**
Principal researcher	**Mr.G.D.Stewart**
Date submitted to RIRDC	**05 JUNE 1998**

Note: **This project forms part of a PhD thesis on poultry welfare by Geoff Stewart, School of Veterinary Science and Animal Production, UQ Gatton College.**

ACKNOWLEDGEMENTS:

We gratefully acknowledge the support of the RIRDC, the University of Queensland and the Queensland United Egg Producers' Association in the provision of working funds and facilities to enable this project to be undertaken.

We also acknowledge the assistance of Mrs Sue Stewart, Mr.Derek Stewart and Mr.Paul Stewart, Dr.Arun Kumar and Mrs Uma Kumar, Mr.Robert Horsbrugh and Sunny Queen Egg Farms in the management design and statistical analysis of the experiment, the collection of eggs, the feeding up, weighing and feather scoring of hens, the daily recording of data during the trial period and egg grading.

We acknowledge the comments and suggestions relating to the preparation of this paper by Dr.John Dingle, Dr.Bob Pym, and Dr.Arun Kumar.

THE PRODUCTION AND WELFARE OF LAYERS HOUSED AT HIGH AND LOW STOCKING DENSITY IN MODIFIED EXISTING CAGE UNITS

Geoff Stewart, 1998
School of Veterinary Science and Animal Production
University of Queensland, Gatton College

SUMMARY

In modified conventional Californian style cages there may be no welfare advantages to the hens resulting from an increase in the space available from 450cm^2/hen to 600+cm^2/hen if the cage remains a relatively barren environment and hens with more space develop more anti social vices.

At both the high and low stocking densities used in this experiment, the double cages with the 1/3 partition (T5 and T6) gave superior outcomes in terms of mortality, egg quality, and gross return per metre^2 cage floor area.

By expanding existing cage areas by partial partition removal, there would be welfare advantages for the hens in having more choice as to the area of the cage they could access at any time. Such a move would create an added welfare advantage in that there would be three watering points available in every cage if nipples or cups are used at no extra cost due to the current code provisions. If trough drinkers were in use, then there would be access to a longer length of water trough space which means more hens could choose to drink from the trough at any one time.

The beneficial effects of extra water access in modified cages could be significant under Australian summer conditions in semi controlled environment layer houses.

All treatments at the lowest stocking density had poorer food conversion, ate more feed, and became more obese which could lead to fatty liver problems towards the end of lay particularly during Australian summer months. Obese hens are the first to die in sudden onsets of hot weather.

Cannibalism through vent 'peck out' in this experiment occurred in only two hens, both from the double cage low stocking density treatment (T3). The level would undoubtedly have been considerably higher if the hens had not been beak trimmed.

The highest mortality (mainly Mareks disease) occurred in the double cage low stocking density treatment (T3) which suffered the greatest amount of feather pecking and was thought to be at least partially stress induced.

Average egg weight was significantly higher in the low stocking density groups and cracked and dirty eggs were also reduced with the exception of treatment T3 (the double cage low stocking density group).

The best feather condition at the end of lay was in hens in treatment T2 (two hens/single cage) which demonstrates the value of small group size. in terms of plumage protection. If the shed environmental conditions are warm, then

replacement of lost and damaged feathers does not proceed as it might otherwise do if the hens needed their feathers for insulation against cold conditions.

If legislation were enacted to force a greater cage floor area per hen which would mean a greater feed trough length per hen, diets would require to be reformulated to allow for the expected higher consumption.

If the Australian Code of Practice (Domestic Poultry) was adjusted to meet the current European Economic Council Poultry Directive 88/166/EEC which specifies a minimum of 450 cm^2 per hen for four or more hens in cages and a minimum of 550cm^2 per hen for three hens in cages, then it would be both feasible and economically sound to partially remove existing partitions between 30cm wide x 45cm deep cages and maintain present stocking densities per shed.

The partial removal of partitions would not interfere with current door openings and would maintain cage and floor strength if the 1/3 partition were kept at the front of the cage.

Even though the egg size, egg numbers, and egg quality were better on average for the low stocking density groups compared to the higher density groups, the sheer volume of production generated from the latter hens means that the producer will generate a much better return on investment by housing his stock at the current (higher) density.

A further consideration for most partially controlled environment egg laying sheds is that if stocking density was reduced in Australia there would be a reduction in the body heat generated which is used to maintain shed (hen) warmth in winter. This could have significant welfare implications on many farms.

Net returns per square metre of cage floor space were in the order of 25% less for the low stocking density treatments compared to those of the high stocking density groups.

If the producer cannot see positive welfare benefits for his stock by adopting lower stocking densities, then it will be difficult to obtain industry support for a change to a lower stocking density. Even if welfare benefits were demonstrated, it would also be difficult to convince lending institutions that more money should be invested into the enterprise for welfare purposes if production and hence return to investment is not improved.

Cage enrichments (e.g. pecking balls or other objects of interest and perhaps choice feeding including unmilled grain or coarse chopped hay or roughage may prove successful in reducing boredom vices such as feather pecking and cannibalism whether or not stocking density were legislatively reduced.

PRODUCTION AND WELFARE OF LAYERS HOUSED AT HIGH AND LOW STOCKING DENSITY IN MODIFIED EXISTING CAGE UNITS

Papers published as a result of this project.

STEWART, G.D., 1994. Cage modifications and how birds perform under different climatic conditions. *Proceedings Queensland Poultry Science Symposium* **3**:65-71. University of Queensland, Gatton College.

STEWART, G.D., 1996. Performance and welfare of Australian genotypes in alternative and modified cage designs. *Proceedings Australian Poultry Science Symposium* **8**:78-85. University of Sydney, New South Wales.

1 INTRODUCTION

The need for and the use of space by hens is a very complex issue for which it is difficult to establish an absolute basis. Body size, genetic strain, hen activity, position in the peck order, number of hens in the group and environmental temperature are some of the factors that prevent any generalization about the space required and the best cage configuration in which to house intensively kept laying hens.

Approximately 48% of all the commercial laying hens housed in cages in Australia are kept in three hen cages (Stewart, 1993) commonly referred to as a ‘California cage’ with dimensions of 300 mm wide x 450 mm deep - normally with watering points at the back and feed trough at the front. The current Australian Code of Practice specifies a maximum stocking density of 450 cm^2/hen for <u>three</u> or more hens/cage. There is mounting pressure in Australia and Europe to increase the minimum space available to layers in cages to at least 600cm^2/hen for three or more hens per cage. Should stocking densities be decreased by legislation either by space/hen *per se* or by establishing a minimum number of hens which may be held at a particular maximum density (e.g. like the European Union Directive 88/166/EEC which specifies a minimum floor space of 450 cm^2/hen for four or more hens and a minimum space of 500cm^2/hen for three hen cages), the important question is ‘what can Australian producers do, if anything, to modify their existing cages and would these modifications be welfare positive and economically sound ?'

The objectives of this experiment were:

(1) To determine how effectively existing cage systems for layer housing in Australia could be modified if the stocking density specifications for the Australian 'Code of Practice – Domestic Poultry' were decreased.

(2) To compare the effect which the 1992 proposed changes to the 'Code' may have on the production and welfare of hens in modified cages with hens in cages under the present system.

(3) To predict the economic impact that possible changes to the permissible maximum stocking density for layers in cages might have on the Australian egg industry.

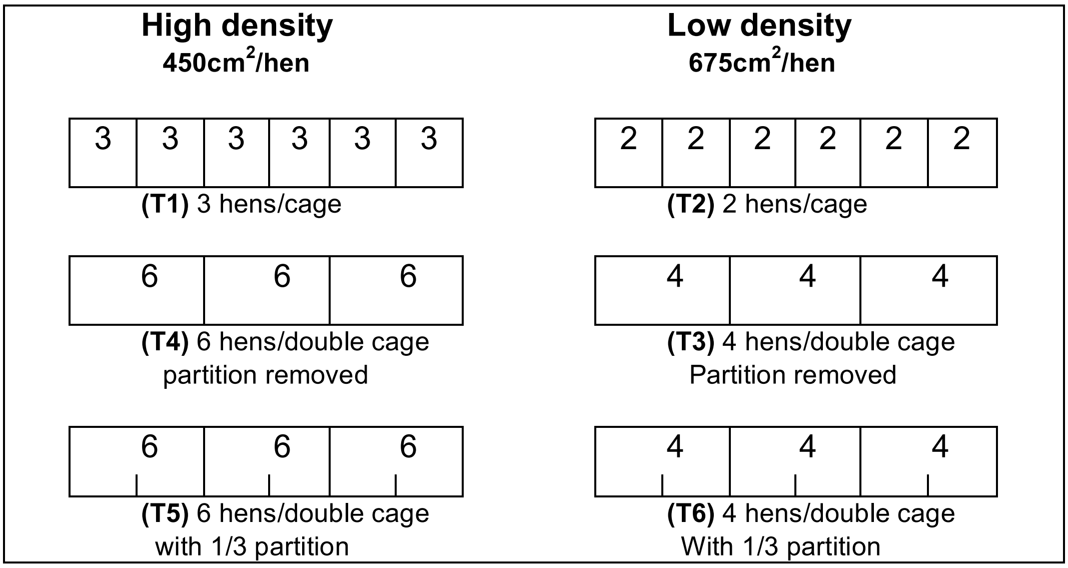
2 MATERIALS AND METHODS

2.1 Experimental Design

Under the present Australian 'Code of Practice -Domestic Poultry' (3rd edition, 1995), three layers with an average weight of less than 2.4kg liveweight may be housed at a stocking density of 450cm^2/hen (Agriculture and Resource Management Council of Australia and New Zealand, 1995). Standard single deck 'California type' back-to-back cages (30cm wide x 45cm deep), were modified by adjustments to the side walls to allow for the movement of hens over a greater floor area - whilst maintaining the same stocking density. The common wall was either completely or partially (2/3) removed between adjacent cages - creating 'double' cages capable of holding six layers (Figure 1). As 'double' cages now capable of holding four or more hens, these modified cages would comply with the European Council directive 88/166/EEC.

The rationale behind removing only part of the common partition was to offer a 'hide' within the double cage for the protection of hens lower in the 'peck order' and to provide extra cage floor support at the front of the cage next to the feed trough (Figure 1).

Fig.1 Schematic diagram of cage modifications and stocking densities



The most common strain of layer in Australia at the time of the experiment (1994), the Hyline-CB, was used for this experiment. The Hyline-CB was then and continues to be a medium bodyweight (approximately 2.2kg) layer which has had a long selection history in Australia and is well adapted to Australian climatic conditions. The pullets had been reared on litter prior to caging.

Complete production data from 'point of lay' (22weeks of age) to 56 weeks of lay were recorded including daily egg production, mortality, feed consumption, progressive body weight, and egg grades. In addition to the production data, feather score at 10 or 12 body points and cage condition (evidence of sagging or bounce due to removal of alternate cage partitions) were also monitored throughout the experiment.

The trial was conducted in a gable type shed with ridge ventilation, temperature activated fans, and relatively old double sided aluminium foil ceiling insulation with external white roof paint (Plate 1).

Plate 1 The experimental ridge ventilated gable shed looking from the NW corner

Six replicates of each of the six treatments making a total 36 groups with a total of 540 hens were tested. Hens were randomly assigned to each treatment and treatments were randomly assigned to each of six cage rows within the shed.

High density groups (450cm^2/hen)	**Low density groups (675cm^2/hen)**
T1 = 3 hens/single cage	T2 = 2 hens/single cage
T4 = 6 hens/double cage	T3 = 4 hens/double cage
T5 = 6 hens/double cage + 1/3 partition	T6 = 4 hens/double cage + 1/3 partition

Feather condition was scored on all hens on a scale of 1-5 (1 = large areas of bare skin: 2 = small patches of skin showing. 3 = patches of worn/broken feathers. 4 = good feathering but feather wear appearing. 5 = perfect feather condition).

Feather scoring at six months of lay was done on 10 body points (Plate 2).

Plate 2 The 10 body positions for feather scoring at six months of lay

P1=Front neck; P2=Upper chest; P3=Left neck; P4=Left side; P5=vent area; P6=Base of tail; P7=Centre back; P8=Back of neck; P9=Right side;P10=Right neck.

The overall feather scores at the end of lay (12 months of age) showed a much greater variation compared to the six month score. In some groups there was significant feather loss below the vent and towards the posterior keel region and consequently, an extra two body points were added for scoring (Plate 3).

Plate 3 The 12 body points for feather scoring at the end of lay
P1 - Front neck: P2 - Upper Chest: P3 - Left neck: P4 - Left side: P5 - Vent area:
P6 - Lower pubic region: P7 - Posterior keel area: P8 - Base of tail: P9 - Centre back:
P10 - Back of neck: P11 - Right side: P12 - Right neck.

Feed consumption was recorded weekly for each group for the entire laying period. The feed supplied was formulated and milled at the University feed mill and was designed for an average daily intake of 110g.

The facilities used in this trial were very old and troughs were only separated at each 1.8m length. Consequently hens could 'pile up' feed in sections of the trough and some wastage did occur. However this was considered to apply evenly across all groups throughout the laying year.

3 RESULTS AND DISCUSSION

The results are presented in the following order: production and mortality; feed consumption; egg grades; economic analysis; body weights; feather scores; comparison of feather scores in 'like cage' configurations; general discussion and recommendations; welfare; legislation.

3.1 Production and Mortality

The mean production and mortalities of the hens in the six treatments to 56 weeks of lay is shown in Figure 2 and Table 1.

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Not significantly different at $P<0.05$: SEM(HDP%) = 1.90 SEM(HHP%) = 2.35

Hen day production (HDP) is the actual average daily production and does not take mortality into account.
Hen housed production (HHP) is the production expressed as a percentage of the hens housed and takes mortality into account.

Although not significant, treatment T2 (2 hens/single cage) had the highest hen day and hen housed production of any group, and all the low density groups had higher hen day production (1% -3%) compared to their corresponding high density groups.

In both the high and low density treatments the double cages with no partition (T4 and T3) had the lowest hen day production for any of the treatments at that stocking density.

Although there were no significant differences in mortality or production when comparing the mean of all the high density groups to the mean of the low density groups, there was a consistent trend for the low density groups to have a higher hen day production as well as hen housed production (Table 1).

Table 1 The effect of high and low stocking density on mortality and production from point of lay(22 weeks) to 78 weeks of age

Treatment	Mortality %	HDP %	HHP %
High density	11.73	80.75	75.46
Low density	12.50	82.57	76.57
SEM	6.69	3.29	4.06

Not significantly different at $P<0.05$

Expected mortality for laying hens in Australia is about 0.75 to 1.5 per cent per month.

The combined mortality rates for both high and low density treatments appeared to be low and was misleading as it masked the results of individual treatments.

As shown in Figure 3 the highest mortality occurred in treatment T3 (four hens /double cage with a stocking density of 675cm^2/hen followed by treatment T4 (6 hens per double cage with a stocking density of 450cm^2/hen.

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Different superscripts after each value denote significant difference at $P<0.05$: SEM = 3.86

Readers note: For ease of comparison, where possible all figures in this paper will show each treatment in the same hatching. Similar direction of hatch lines will allow easy comparison of like cages - T1 (3 hens/single cage) can be compared with T2 (2 hens/single cage). Similarly, T4 can be compared with T3 (both double cages), and T5 with T6 (both double cages with 1/3 partition).

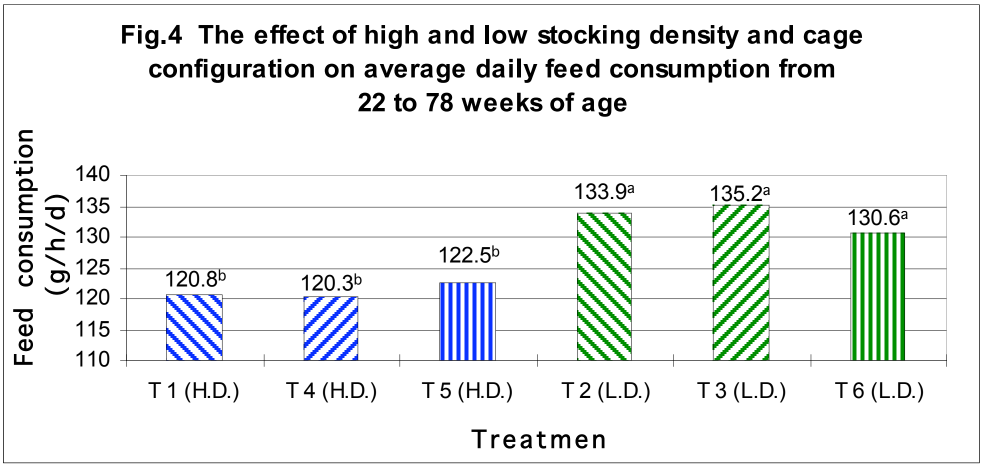
From observation, there was more interaction between hens in treatments T4 and T3 compared to the other treatments and this may be due to the effective extra space created by the removal of the cage partitions. There was also more feather pecking in the vent and tail/back regions in these groups. It is suggested that the extra stress may have been associated with higher mortality in treatments T3 and T4. The lower mortality shown in treatments T5 and T6 indicates that there may be value in having a partial partition in double cages with larger group sizes.

The cage configuration for the hens in treatment T3 (four hens per double cage at $675cm^2$ per hen) is illustrated in Plate 4.

Plate 4   Treatment T3 with four hens/double cage ($675cm^2$/hen) had the greatest freedom of movement and the highest mortality

3.2 Feed Consumption

The mean daily feed consumption for each of the six treatments is shown in Figure 4.

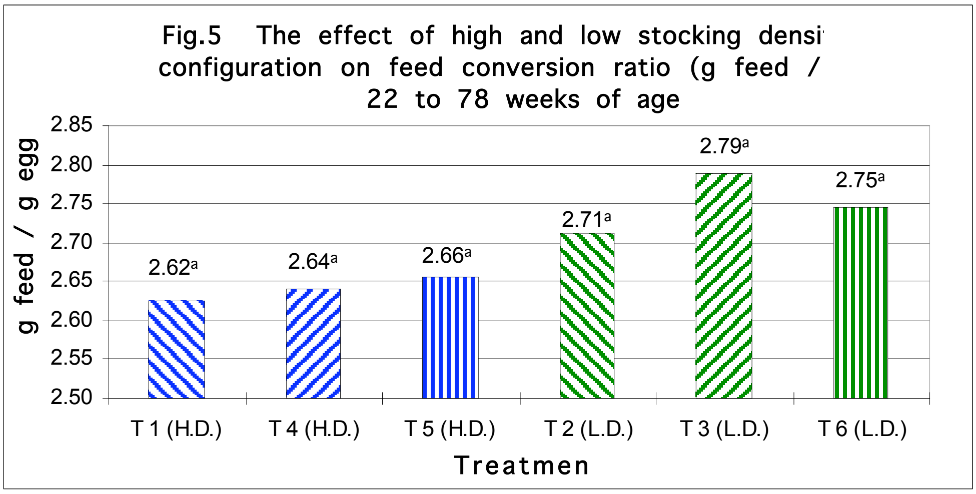


Different superscripts after each value denote significant difference at $P<0.05$: SEM = 2.42

The average daily feed consumption for the combined low density groups was significantly higher (12.1g or 9.9%) than that for the combined high density groups ($P<0.05$).

Access to the feed trough through less competition was considered to be the major reason for increased feed consumption in the low density groups. The smaller group size would also contribute to less hen/hen interaction.

As shown in Figure 5, the feed conversion ratio mirrored the feed consumption pattern above with treatment T3 showing the worst efficiency, but was not significant different at ($P<0.05$). This may be partly due to the extra aggression which was observed in the hens in this group and also to the fact that they tended to pile up the feed in the trough resulting in greater wastage which could not be measured.



Different superscripts after each value denote significant difference at P<0.05: SEM = 0.06

There was a significant difference between the mean feed conversion ratio for the high density groups of 2.63g feed per g egg compared with the mean of the low density groups at 2.75g feed per g egg (P<0.05).

As shown in Table 2 stocking density and cage configuration had a significant effect on the feed consumed per dozen eggs produced. The higher feed consumption per dozen eggs in the low density groups was partly the result of greater access to the feed trough with fewer hens per cage. From an economic point of view however, the number of eggs produced per gram of feed eaten is not as important as the grade size of the egg produced. Commercial marketing returns do not show a direct relationship with egg mass *per se* but rather with grade size. Very small and extra large eggs are often paid for at a lower price per unit weight as they are not in as popular demand as other grades of egg.

Table 2 The effect of high and low stocking density and cage configuration on the average feed consumption per dozen eggs from 22 to 78 weeks of age

Treatment	Av. feed (kg) /dozen eggs
T1 H.D.(3 sngl)	1.79^{c}
T4 H.D.(6 dbl)	1.79^{c}
T5 H.D.(6 dbl 1/3 partit.)	1.83^{bc}
T2 L.D.(2 sngl)	1.91^{ab}
T3 L.D.(4 dbl)	1.97^{a}
T6 L.D.(4 dbl 1/3 partit.)	1.93^{a}
SEM	0.03
H.D. Mean	**1.80^{y}**
L.D. Mean	**1.94^{x}**

Different superscripts denote significant difference at P<0.05

The low density hens had a poorer feed conversion efficiency (1.94 kg feed/dozen eggs) compared to the high density groups (1.80 kg feed/dozen eggs) ($P < 0.05$). At a cost of $260/tonne layer feed, the feed cost per dozen eggs was 46.8cents for the high density hens and 50.4cents for the low density hens. (For further discussion of economic factors see section 3.4 'Economic Analysis'.)

3.3 Egg grades

Stocking density and cage configuration had a considerable effect on shell quality, shell condition, egg size and grade out percentage which ultimately affected gross returns.

The grade size percentage of all first quality eggs produced by hens in the six treatments showed considerable variation in the numbers of 45g-52g, 59g-66g and 66g-73g eggs produced. These results are shown in Table 3.

Table 3 The effect of high and low stocking density and cage configuration on grade size percentages of first quality eggs from 22 to 78 weeks of age

Treatment	<38g %	38g-45g %	45g-52g %	52g-59g %	59g-66g %	66g-73g %
T1 H.D. (3 sngl)	0.08^{a}	2.86^{a}	21.47^{a}	40.40^{a}	20.84^{b}	3.44^{ab}
T4 H.D. (6 dbl)	0.13^{a}	2.47^{a}	19.86^{ab}	41.71^{a}	23.65^{ab}	2.09^{b}
T5 H.D. (6 dbl) 1/3 partit.	0.09^{a}	2.06^{a}	20.17^{ab}	40.78^{a}	24.48^{ab}	2.84^{ab}
T2 L.D. (2 sngl)	0.19^{a}	2.38^{a}	16.89^{b}	40.30^{a}	28.46^{a}	4.90^{a}
T3 L.D. (4 dbl)	0.19^{a}	2.20^{a}	17.58^{ab}	43.86^{a}	26.48^{ab}	3.44^{ab}
T6 L.D. (4 dbl) 1/3 partit.	0.08^{a}	2.09^{a}	20.30^{ab}	40.98^{a}	26.64^{ab}	3.83^{ab}
SEM	0.06	0.51	1.57	1.58	2.09	0.79
H.D. Mean	**0.10^{y}**	**2.46^{x}**	**20.50^{x}**	**40.96^{y}**	**22.99^{y}**	**2.79^{y}**

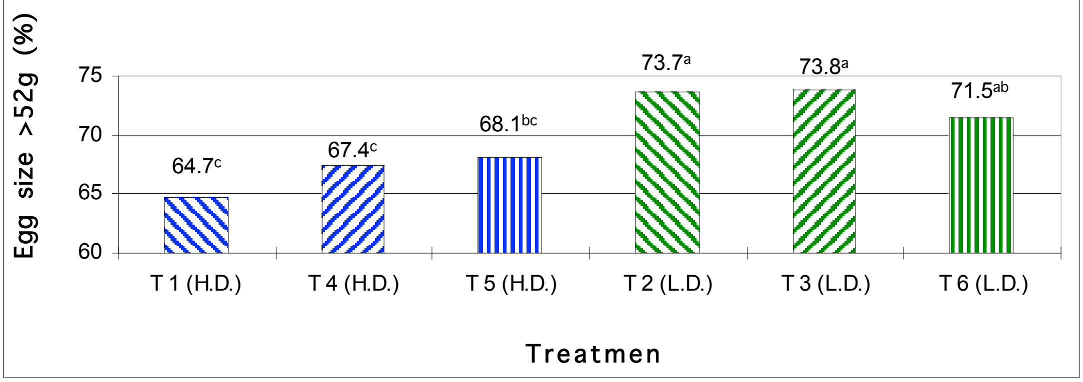
L.D. Mean	0.15^x	2.22^y	18.26^y	41.71^x	27.19^x	4.06^x

Different superscripts within a column denote significant difference at P<0.05
H.D. and L.D. means were analysed as a separate series

The significant difference in the production of 45g-52g eggs between treatments T1 and T2 clearly demonstrated the effect of stocking density on egg size that as stocking density decreased, egg size increased. The only difference between treatments T1 and T2 is the addition of one extra hen in the T1 groups resulting in the production of 4.95% more small eggs (<52g) than the T2 treatments. At the other end of the egg grade scale, the T2 groups produced 8.78% more large eggs (>52g) than the T1 treatments.

For egg weight, an analysis of the grade sizes of the first quality eggs showed that the low density groups on average produced 73.2 % of eggs greater than 52g whereas the high density groups produced on average only 66.7 % of 52g or greater sized eggs. Treatment differences are shown in Figure 6. Commercial egg pricing favours egg sizes of 52g or greater as these eggs are in greater demand by consumers, consequently the production of larger eggs (>52g) has an important

Fig.6 The effect of high and low stocking density and cage configuration on egg size (> 52g) from 22 to 78 weeks of age



bearing on farmers' returns and profitability .

Different superscripts after each value denote significant difference at P<0.05: SEM = 0.71

Stocking density and cage configuration had a significant effect on average egg weight (P<0.05). Average egg weight was greater in the low density (58.5g) than for the high density stocked hens (56.9g) (P<0.05).

The effect of stocking density and cage configuration on average egg weight is illustrated in Figure 7.

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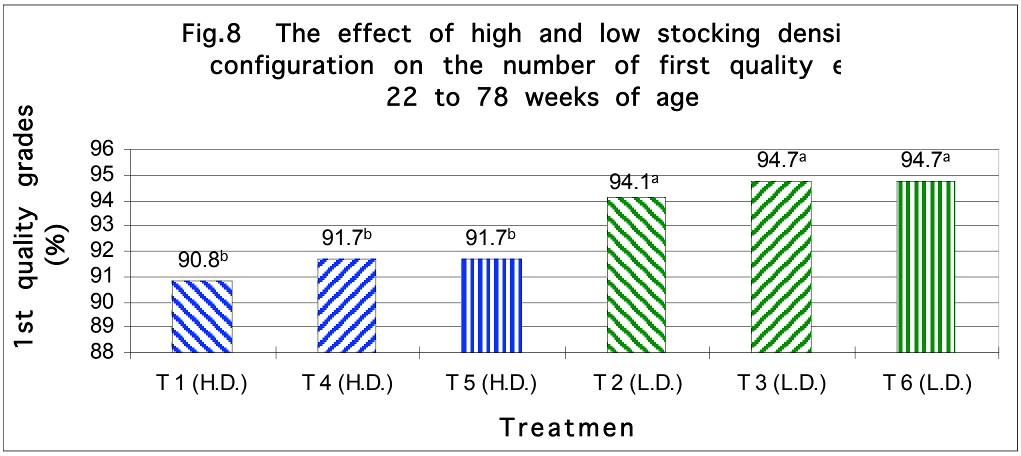
Different superscripts after each value denote significant difference at P<0.05: SEM = 0.71

There was no significant effect (P<0.05) of cage configuration on average egg weight within either the high or low stocking density treatments. However, the combined high density treatments produced a significantly lower average egg weight (56.96g) compared to the combined low density treatments (58.83g) (P<0.05). Treatment T4 (six hens per double cage) had the lowest average egg weight of all the treatments and this group also had the lowest feed consumption (Figure 4).

Figure 8 shows that the high density treatments produced significantly fewer first quality eggs (91.4%) than the combined low density treatments (94.5%) (P<0.05). The difference in first quality eggs was associated with higher numbers of cracked and dirty eggs as well as a higher percentage of 'others' including misshapen, weak and porous shells, blood spots, tremulous air cells etc.

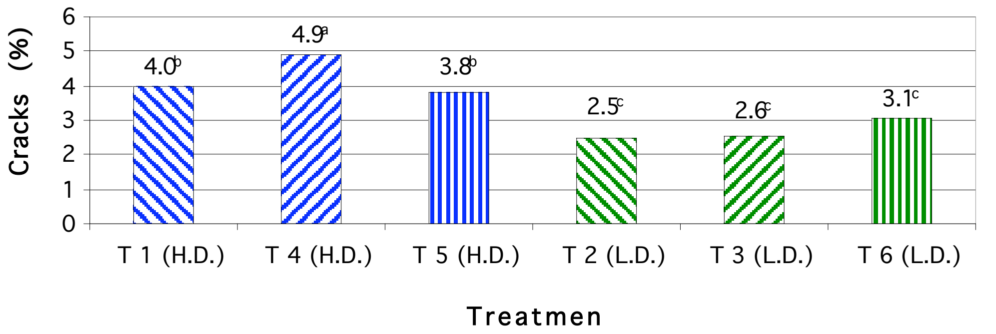


Different superscripts after each value denote significant difference at P<0.05: SEM = 0.38

Overall, the high density groups had significantly more cracked eggs (4.92%) than the low density groups (3.98%) (P<0.05). This was thought to be caused by the eggs having to roll through the feet of more hens to reach the roll out tray and also there would have been more collisions in the roll out trays due to the greater number of eggs present (i.e. the high density groups had more eggs in the same length of roll out space as the low density groups).

The highest number of cracks was recorded from treatment T4 (6 hens/double cage - no partition) as shown in Figure 9. This is consistent with the 'collision potential' statement in the above paragraph.

Fig.9 The effect of high and low stocking densi
configuration on the percentage of cracked eg
22 to 78 weeks of age



Different superscripts after each value denote significant difference at $P<0.05$: SEM = 0.23

As illustrated in Plate 5 the cages in treatment T4 were not supported in the centre as were the other double high density cages with the 1/3 partition. Consequently the floors in treatment T4 tended to sag resulting in more eggs rolling into the centre front of the cage than with the other cages resulting in more egg collisions. These unsupported cage floors and roll out trays also suffered from more 'bounce' due to the movement and weight of the six hens within the double cage which may also have contributed to the increased the percentage of cracked eggs.

From a welfare point of view, sagging cage floors mean an increase in the slope of the floor and this may lead to increased foot pad damage due to slippage on the steeper wire floors.

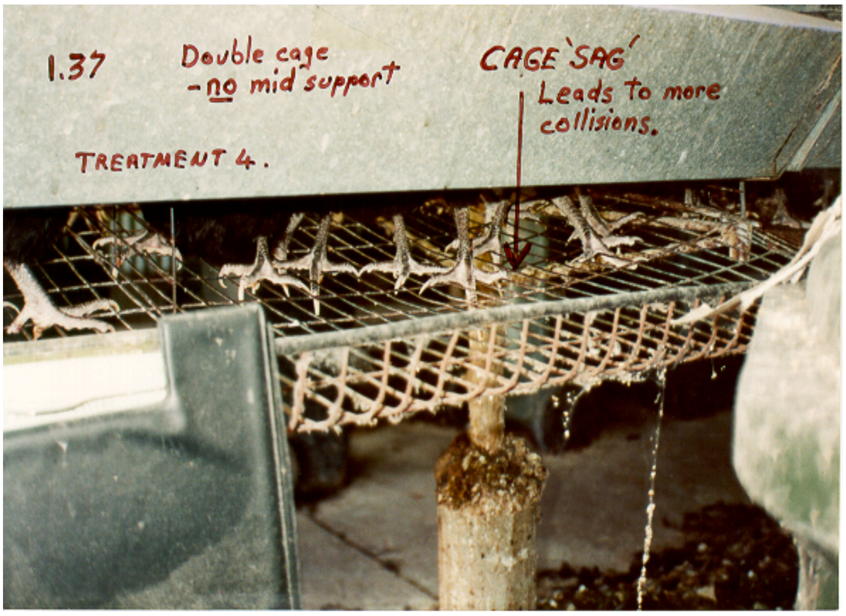
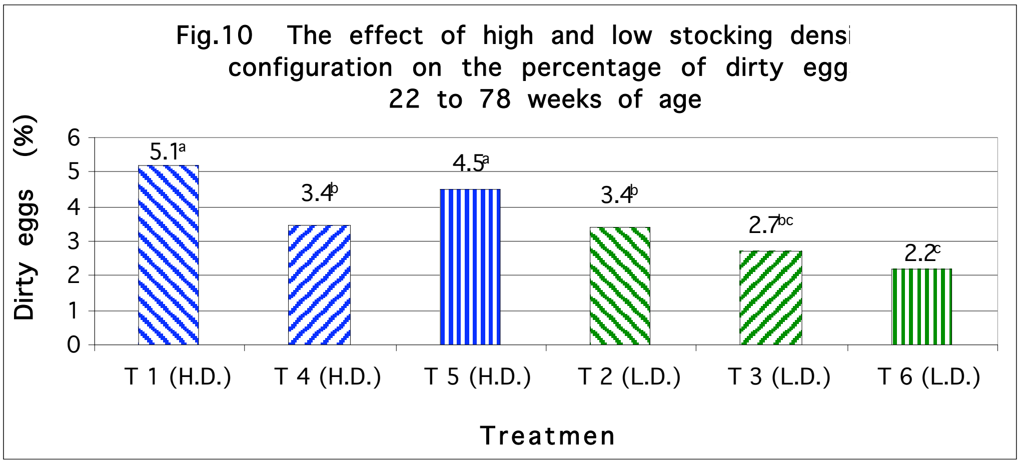


Plate 5 Six hens per double cage showing 'floor sag' due to lack of structural support

The standard cage with three hens (treatment T1) had the highest percentage of dirty eggs. This was thought to be caused by the greater likelihood of the eggs becoming dirty from excreta in the narrow congested cage as eggs were almost entirely laid in the back of the cage and had to pass under the hens in the front of the cage before reaching the roll out tray. Wide front or 'reverse' cages reduce the dirty egg problem as there is less distance and less feet under which the eggs have to pass in order to reach the roll out trays. Treatment T6 (four hens per double cage with a 1/3 partition) had the least number of dirty eggs of all treatments as shown in Figure 10.



Different superscripts after each value denote significant difference at $P<0.05$: SEM = 0.28

Cage configuration and stocking density significantly affected the percentage of second quality eggs produced throughout the experiment. The average proportion of second quality eggs was greater in the high (8.58%) than the low (5.49%) stocking density hens (P<0.05). A comparison of the percentage of total second quality eggs from each treatment is presented in Figure 11.

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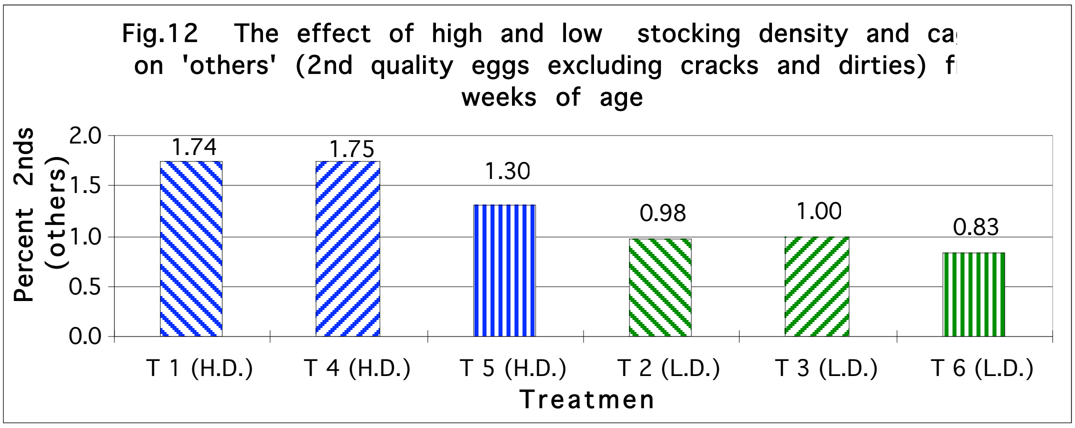
There was a significant increase in total second quality eggs as stocking density increased. Part of this increase would be due to cracks caused by the physical movement of the egg through more sets of legs and more collisions in the roll out trays, but there were also more shell defects and internal quality problems in the high stocking density treatments. There was no effect of cage configuration on this trait. Overall, the high density treatments produced a significantly higher percentage (8.57%) of second quality eggs compared to the low density treatments (5.49%)(P<0.05).

There was an increase (not significant) in the 'others' grade category in each of the higher density treatments compared to the low density treatments. This difference could indicate that the hens in the high density treatments may have suffered more stress due to the actual numbers of hens in each cage leading to higher levels of interaction between individuals (Figure 12).



Not significantly different at P<0.05: SEM = 0.41

Although the results from individual treatments showed no significant differences possibly due to the large variations between groups within treatments, when compared together, the high density treatments had a significantly higher incidence of egg 'others' (quality defects) (1.76%) compared to the low density treatments (0.99%)(P<0.05).

3.4 Economic analysis

The gross economic return for egg production is based on the number, grade size and quality of the eggs produced. Stocking density or cage configuration did not significantly affect the gross return per hen housed although the trend was consistent that the hens stocked in the low density treatments showed an improvement in returns per hen housed due to larger egg size and a lower level of second quality eggs particularly cracks and dirties. Table 4 shows the gross return realized for each group. It does not take into account the costs of labour or feed or any of the overhead costs.

Table 4 Comparison of gross egg returns as affected by stocking density and cage configuration

Treatment	Gross return per doz. ($)	Gross return per hen housed ($)
High Density	1.66^{b}	35.12
Low Density	1.71^{a}	36.59
SEM	0.01	1.16

Gross return per hen housed was not significantly different at P<0.05

* Returns calculated using average gross prices paid to South Queensland producers in 1996 (excluding any grading, marketing, and administrative charges) as follows:
Grade prices: 38g-45g ($1.07/doz): 45g-52g ($1.69/doz): 52g-59g ($1.79/doz): 59g-66g ($1.83/doz): 66g-73g ($1.91/doz): second grades ($1.20/kg)
NOTE: the above prices are relevant to South Queensland. for 1996/97 but actual prices will vary between regions and states

In both the high and low density groups the double cage with no partition gave the poorest returns on a hen housed basis, yet these hens had the greatest amount of usable cage space and the greatest access to feeding space of any of the treatments at that stocking density.

In the case of treatment T4, a lower return was due to a higher percentage of cracks and second quality eggs and higher mortality compared to the other high density groups. For treatment T3, the major factor in producing a poorer gross return was the significantly higher level of mortality experienced in this group compared to the other low density groups (Figure 13).

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Not significantly different at $P<0.05$: SEM = 1.16

Using the average pricing schedule employed in South Queensland, the mean gross return per dozen eggs produced was significantly higher for all the low density groups ($1.71) compared to the high density groups ($1.66) ($P < 0.05$). Individual treatment returns are shown in Figure 14. The major reasons for this difference in gross return per dozen was that the low density hens produced less cracks, less dirties and less 'others' and they consistently produced eggs of a higher average egg weight.

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From a financial accounting point of view, producers measure productivity in terms of return per square metre of cage or shed area. Although the low density hens gave a better return per dozen eggs produced, one third less hens could be housed in the same space compared to the high density treatments and this considerably affected the return per unit of cage area.

The major production factors that affect return per dozen eggs are :

1. Mortality/morbidity
2. Hen housed production
3. Egg size/grade outs
4. Feed consumed and cost/tonne
5. Labour costs
6. Pullet costs

Other costs which are shared over the whole enterprise are :

7. Housing capital costs

8. Repairs and maintenance
9. Depreciation
10. Medication/fuel/electricity etc
11. Interest accrued on investment

Differences in production due to overall welfare improvements or impediments caused by the different stocking densities and cage configurations were expressed as a component in the total productive output thus affecting the net returns for each group.

In this experiment the emphasis was placed on the effect that the treatments had on the welfare indices of mortality, feather condition, and feed consumption. The above three indices have a direct bearing on egg number, egg size, shell quality, hen housed production and ultimately the return per hen housed.

From the producers' point of view, the most critical economic measure is the return on investment and this can be measured for comparison between different cage production systems as the return per unit of cage floor area (Figure 15). This comparison shows that the high density hens had a considerably greater gross return/m^2 of floor area than the low density hens.

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Different superscripts after each value denote significant difference at $P<0.05$: SEM = 13.91

Returns calculated using average gross prices paid to Sth. Qld. producers in 1996 (excluding any grading, marketing, and administrative charges) as follows:
Hen depreciation = started pullet price ($6.50) – cull value ($0.20)
Gross return = gross value of eggs – (feed costs plus hen depreciation)

3.5 Body weights

The final body weight of hens within treatments varied according to the stocking density to which they were subjected. The hens in each of the low density treatments ate more feed than those in the high density groups and this was reflected not only in greater egg size but also in increased body weight throughout the entire period of lay, as shown in Figure 16.

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Different superscripts after each value denote significant difference at P<0.05: SEM = 2.15

There was a substantial increase in overall weight gain in the hens given 675cm^2 of floor space per hen compared with the hens at the higher stocking density within each cage configuration. The increased weight gain could have welfare implications in the latter part of lay particularly in summer as discussed in chapter three. There are also disease implications for heavier fatty hens (particularly from fatty liver disease syndrome) if the hens are approaching the end of lay and the summer temperatures are extreme.

The average body weight at 56 weeks of lay of the high density treatments (2.2kg) was significantly lower than the average body weight of the low density groups (2.4kg) ($P < 0.05$). As indicated from Figure 3.16, there was a significantly higher average increase in bodyweight of 30.0% over the point-of-lay weight for the low density hens compared to an average 19.7% increase in body weight for the high density hens ($P<0.05$) as shown in Table 5.

Table 5 The effect of high and low stocking density on increase in body weight from 22 to 78 weeks of age

Treatment	Original body weight kg	Final body weight kg	Percentage increase
H.D. Mean	1.858[a]	2.204[b]	19.7[b]
L.D. Mean	1.846[a]	2.271[a]	30.0[a]
SEM	0.02	0.03	2.15

Different superscripts in each column denote significant difference at P<0.05

Visual appraisal of the body cavity of end of lay hens from the low density groups showed considerably more abdominal fat deposits around the organs (particularly the liver which was tending towards a pale yellow colour) than did end of lay hens from the high density groups. However, actual liver fat content which might have shown a tendency to develop ‘fatty liver’ in the low density higher energy consuming groups was not assayed in this experiment.

Apart from possible effects on fatty liver and kidney syndrome, the body weight increase of the low density groups could also cause the hens to suffer more

from heat stress if they were approaching the end of lay in summer periods.

Irrespective of the treatment, the hens in this experiment gained most weight in the first three months after caging at point of lay. The average percentage increase in body weight for each group during the first three months of lay is shown in Figure 17.

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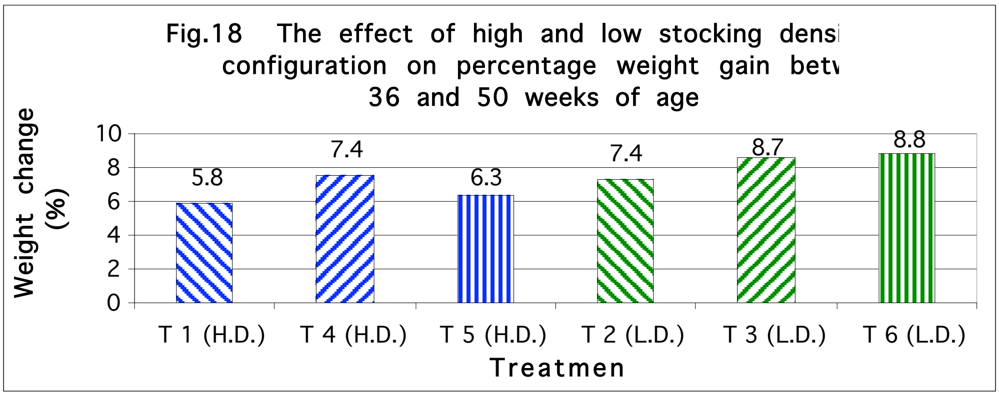
Different superscripts after each value denote significant difference at $P<0.05$: SEM = 1.29

The highest body weight gain (15.4%) in the three months immediately after caging occurred in treatment T2 (two hens per single cage) which probably reflects the easy access to feed space and the low level of aggression displayed by the hens when only two hens are placed in a cage (Plate 6).

Plate 6 Treatment T2 - Two hens per standard 30cmx45cm cage. Hens in this treatment ate most and achieved the highest body weight particularly over the early laying period.

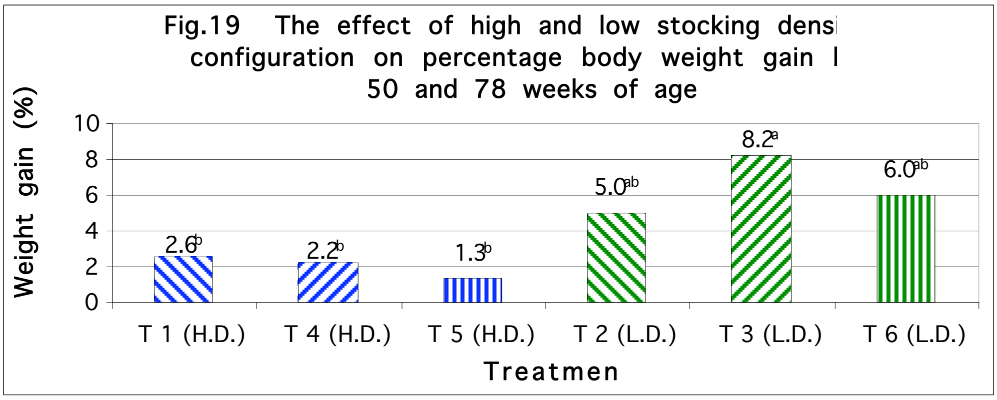
During the period three to six months after point of lay, there was no significant difference in the rate of body weight increase between any of the groups (Figure 18). At three months of lay, the hens had passed their production peak.



Not significantly different at $P<0.05$: SEM = 1.47

Although it tended to be higher for the low density treatments, there was no significant difference in the rate of body weight gain between the combined low density treatments or the combined high density treatments.

Figure 19 shows that during the last period of lay from six to twelve months, there was a significant increase in the body weight of the low density hens compared to those in the high density treatments.



Different superscripts after each value denote significant difference at $P<0.05$: SEM = 1.33

The greatest difference in average body weight increase between the high and low density groups occurred in this final period where the high density groups averaged a significantly lower weight increase (2.33%) compared to that of the low density groups (6.40%) ($P<0.05$). The much greater increase in body weight in the low density groups during the last six months of lay was thought to be due to the relative ease of access to the feed trough. This was supported by the fact that in both the high and low density groups, the treatments with the greatest increase in body weights were the ones which had suffered the highest mortality over the laying year (i.e. T4 and T3 respectively). Therefore these two groups had an effectively lower stocking density than the other treatments in their high or low density groups.

No explanation can be given for why there was such a low increase in body weight for treatment T5 compared to all other groups. The hens in this group were the lightest hens of any group at the end of the experiment even though they were the second heaviest on average at the start. The 1/3 partition left in the cage of the T5 groups did reduce the useable feed trough space as the partition was placed adjacent to the feed trough and this slightly reduced unimpeded access to the complete length of the feed trough (Plate 7).

Plate 7 Treatment T5 showing the effect the internal partition has on unimpeded access to the whole feed trough. Hens tend not to use the feed trough immediately adjacent to the partition.

Visual observations showed that hens in the double cages with one third partition rarely used the feed trough immediately adjacent to the partition or for that matter, the space immediately adjacent to the cage sides, and so the 'effective feed trough length' was less than that available to hens at similar stocking densities in open double cages.

This was supported by the feed consumption data for the whole of lay (Table 2) where the feed consumption for the groups with four hens per double cage with 1/3 partition had a 3.0% lower average daily feed consumption over the whole period of lay than did the comparable groups of four hens per double cage with no partition (Plate 7).

The body shape of hens accounts for the poor usage of feed trough space adjacent to cage sides as a hen addressing the feed trough squarely will need to stand approximately 50-70mm in from the cage side to avoid shoulder/wing rub on the cage partition.

3.6 Feather scores

(a) After three months of lay

A trial feather score was undertaken across all groups at the end of the first three month period. There were no discernable differences between the treatments in feather score at this time.

(b) At six months of lay

Feather condition at six months of lay showed significant differences due to stocking density and cage configuration. Greater feather wear was evident for the hens in the high density groups compared to the hens in the low density groups. On a scale of 5 to 1 where 5 is perfect feathering and 1 is bare skin, the hens in the high density treatments averaged an overall score assessed over 10 positions of 3.5 compared to hens in the low density treatments of 3.9 (significant at $P<0.05$).

The major difference in feather condition between the groups can be seen by comparing treatment T2 (two hens per single cage) with treatment T5 (6 hens per double cage with 1/3 partition) (Figure 20). The T2 hens had better plumage at every position scored and consequently had a significantly better overall score.

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Different superscripts after each value denote significant difference at P<0.05: SEM = 0.21

Treatment T5 (six hens per double cage at 450cm^2/hen with 1/3 partition) had the worst overall feathering at six months of lay. This may be due to the high stocking density and the intrusion of the 1/3 partition into the cage which would have created more locations on which the hens could rub in moving about the cage. Treatment T2 (2 hens per single cage at 675cm^2/hen) showed feather condition was less affected when cage density was low and when there were low numbers of hens per group.

The feather score 'sum' for the combined low density treatments was significantly higher (average score 3.9) at six months of lay than for the combined high density treatments (average score 3.5) (P<0.05).

Individual feather scores at six months of lay for various body parts showed that feather wear was occurring at different rates depending on stocking density and cage configuration (Table 6).

Table 6 The effect of high and low stocking density and cage configuration on average feather condition of ten body points at six months of lay (5 = covered, to 1 = bare)

Treat-ment	P1 Front Neck	P2 Upper Chest	P3 Left Neck	P10 Right Neck	P4 Left Side	P9 Right Side	P5 Vent Area	P6 Tail Base	P7 Centre Back	P8 Neck Back
High Density	2.29^y	2.68^y	3.32^y	3.28^y	3.80^y	3.82^y	4.13^x	3.91^x	4.21^x	3.79^y
Low Density	2.71^x	3.34^x	3.90^x	3.71^x	4.71^x	4.74^y	3.73^y	3.63^y	4.01^y	4.26^x
SEM	0.34	0.48	0.36	0.38	0.22	0.21	0.27	0.40	0.27	0.48

Different superscripts in each column and series denote significant differences at P<0.05

The lower scores for feather condition on the left and right (P4 and P9) sides of the hens in the high density compared to the low density hens indicated the amount of extra inter-hen contact and contact with the cage structure occurring with the high density groups. Similarly greater neck feather wear (P3 and P10) for the high density groups indicated more disturbed activity which was visually observed at times when the hens had their heads through the vertical wire bars over the feeder troughs at the front of the cage.

It should be noted that the feather scores at six months of lay were assessed in mid winter and in most cases, feather condition appeared to be reasonable to the non-critical observer.

3.7 Comparison of feather scores in 'like cage' configurations

The effect of stocking density on feather score across the six treatments is shown in Table 7. The data are paired into "like cage" treatments.

Table 7 The effect of high and low stocking density on average feather condition at ten body points in 'like cages' at six months of lay (5=covered to 1=bare)

TREAT-MENT	P1 Front Neck	P2 Upper Chest	P3 Left Neck	P10 Right Neck	P4 Left Side	P9 Right Side	P5 Vent Area	P6 Tail Base	P7 Centre Back	P8 Neck Back
T1(HD)	2.28^{bc}	2.67^{bc}	3.45^{bc}	3.50^{ab}	3.36^{d}	3.40^{bc}	4.24^{b}	4.33^{b}	4.57^{b}	4.04^{e}
T2(LD)	3.04^{a}	3.71^{a}	4.11^{a}	3.96^{a}	4.82^{a}	4.93^{a}	4.92^{a}	4.96^{a}	4.98^{a}	4.78^{a}
T4(HD)	2.39^{bc}	2.92^{bc}	3.34^{bc}	3.42^{b}	3.74^{c}	3.82^{d}	4.08^{b}	3.95^{b}	4.66^{b}	3.68^{b}
T3(LD)	2.42^{bc}	3.27^{ab}	3.73^{ab}	3.42^{b}	4.65^{a}	4.77^{ab}	3.04^{c}	2.88^{d}	3.27^{d}	4.15^{b}
T5(HD)	2.19^{c}	2.43^{c}	3.14^{c}	2.90^{c}	4.31^{b}	4.21^{c}	4.07^{b}	3.45^{c}	3.40^{d}	3.59^{b}
T6(LD)	2.68^{ab}	3.11^{ab}	3.93^{a}	3.78^{ab}	4.68^{a}	4.61^{b}	3.19^{c}	2.96^{cd}	3.75^{c}	3.92^{b}
SEM	0.34	0.48	0.36	0.38	0.22	0.21	0.27	0.40	0.27	0.48

Different superscripts in each column and series denote significant differences at $P<0.05$

Lower stocking density resulted in better feather condition in all cases at body points P1, P2, P3, P10, P4, and P9. However, at body points P5 (vent) and P6 (tail), the hens held at the lower density had greater feather damage than hens in similar cage configurations at the high density. This was because the hens at 675cm^2 density had much more room to get behind their cage mates and feather peck. It is also thought that as these hens had more feeding space per hen, so the time spent interacting with other hens in trying to get to the feed trough was less than for the hens held at the high density and consequently they had more time to be 'bored' or to practice anti social vices.

(c) At the end of 12 months of lay

Twelve body parts were scored on the 5 (covered) to 1 (bare) scale after 12 months of lay.

As lay progressed and the hens aged, feather wear became much more obvious.

The end of lay score was taken in mid-summer. There was no physiological need of the hens for feather insulation at this time and the mean feather scores were both considerably lower (poorer) than those taken in winter. The mean feather score taken at this time over all the body scoring points for all the high stocking density treatments (T1, T4 and T5) was 2.54 which was significantly worse than the mean feather score for all points for the low stocking density treatments (T2, T3 and T6) at 2.97 (P<0.05).

At the end of lay, the only groups to achieve an overall (average sum of 12 body parts) feather score of greater than 3 (rated as 'average') were the low stocking density treatments T2 (two hens per single cage) and treatment T6 (four hens per double cage with 1/3 partition) (Figure 21).

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Different superscripts after each value denote significant difference at P<0.05: SEM = 0.18

The results indicated that as stocking density increased, the inter-hen contact (collision and rubbing/pushing) increased, and together with the contact of the hens against the wire cage surrounds, led to an increase in feather wear and damage.

Overall, the combined high density treatments feather score at the end of lay was significantly lower (2.54) than the combined score of the low density treatments (2.97) (P<0.05).

At the end of lay, the hens in the low stocking density group T3 (four hens per double cage with no partition) had the worst feather condition of all groups at the vent, tail base and mid back regions. The two hen groups in single cages (T2), even though they had the same stocking density, had the best feather condition at the same points and this showed the advantage of small group numbers in reducing between hen interactions (Figures 22 – 24).

Figure 22 shows the significant difference in feather score of the vent region between the low stocking density treatments T2 and T3 indicating a negative effect of providing more usable space in a still boring cage environment.

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Different superscripts after each value denote significant difference at $P<0.05$: SEM = 0.19

A similar situation of significantly greater feather pecking at the base of the tail is shown for treatments T2 and T3 (Figure 23).

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Different superscripts after each value denote significant difference at $P<0.05$: SEM = 0.28

Figure 24 shows the level of feather pecking at the mid-back region is worst in treatment T3 which had the most usable space of all the treatments (low density double cage with no internal partition).

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Different superscripts after each value denote significant difference at $P<0.05$: SEM = 0.31

Most of the welfare problems associated with cannibalism begin from damage to the vent area, base of the tail and mid back region.

As shown in Tables 8a and 8b, at the end of lay there were a number of places on the bodies of the hens at low density that were significantly better feathered compared to the high density hens in similar cage configurations.

Table 8a Comparison of all body point feather scores at the end of lay for similar cage types with high and low density stocking rates

Treatment	P1	P2	P3	P4	P5	P6
T1 (HD)	2.33^{a}	2.42^{ab}	2.50^{ab}	2.58^{ab}	2.92^{ab}	2.83^{b}
T2 (LD)	2.56^{a}	2.89^{a}	3.11^{a}	3.33^{a}	3.44^{a}	3.67^{a}
T4 (HD)	2.11^{a}	1.67^{b}	2.11^{abc}	2.00^{b}	2.56^{bc}	2.89^{b}
T3 (LD)	2.63^{a}	2.50^{ab}	2.00^{bc}	3.25^{a}	2.38^{c}	1.63^{c}

T5 (HD)	2.17^{a}	1.50^{b}	1.33^{c}	2.17^{b}	3.00^{ab}	2.67^{b}
T6 (LD)	2.33^{a}	2.83^{a}	2.83^{ab}	3.33^{a}	3.17^{a}	3.33^{ab}
SEM	0.22	0.38	0.39	0.29	0.19	0.28

Different superscripts within columns denote significant difference at P<0.05
P1 - Front neck: P2 - Upper Chest: P3 - Left neck: P4 - Left side: P5 - Vent area:
P6 - Lower pubic region

Table 8b Comparison of all body point feather scores at the end of lay for similar cage types with high and low density stocking rates

Treatment	P7	P8	P9	P10	P11	P12
T1 (HD)	2.75^{bc}	2.08^{bc}	3.42^{ab}	3.58^{ab}	2.58^{b}	3.00^{ab}
T2 (LD)	3.67^{a}	3.56^{a}	3.89^{a}	4.00^{a}	3.67^{a}	3.44^{a}
T4 (HD)	2.00^{cd}	2.00^{bc}	2.78^{b}	2.67^{c}	3.00^{b}	2.11^{c}
T3 (LD)	1.50^{d}	1.50^{c}	1.75^{b}	2.75^{c}	3.75^{a}	2.63^{bc}
T5 (HD)	2.67^{bc}	2.33^{bc}	3.33^{ab}	3.00^{bc}	2.83^{b}	2.17^{c}
T6 (LD)	3.33^{ab}	2.67^{b}	2.67^{c}	3.33^{abc}	3.83^{a}	3.50^{a}
SEM	0.30	0.31	0.33	0.25	0.19	0.29

Different superscripts within columns denote significant difference at P<0.05
P7 - Posterior keel area: P8 - Base of tail: P9 - Centre back:
P10 - Back of neck: P11 - Right side: P12 - Right neck

The low density treatment T3 (4 hens per double cage) had the worst feathering of all groups at the vent area (P5), the lower pubic bone region (P6), the posterior keel area (P7), the base of the tail (P8), and the centre back (P9). This indicated that (this) increased feather pecking at these body parts was facilitated by the treatment which provided the greatest amount of cage space per bird (Plate 8).

Plate 8 Hens suffering from severe vent, tail and mid back feather loss which was most prevalent in treatment T3

The feather loss shown in Plate 8 was also seen on individual hens in other treatments, but as the feather score data shows, there were considerably fewer hens affected to this extent in such treatments.

The hens in treatment T3 suffered the highest mortality and showed the lowest returns per unit of cage floor area of any of the treatments.

4 GENERAL DISCUSSION AND CONCLUSIONS

In modified conventional Californian style cages there may be no welfare advantages to the hens resulting from an increase in the space available from $450cm^2$/hen to $600cm^2$ - $675cm^2$/hen if the cage remains a relatively barren environment and the only difference is that the hens are provided with more space which may lead to the development of more antisocial vices. At both the high and low stocking densities used in this experiment, the double cages with the 1/3 partition (T5 and T6) gave superior outcomes in terms of mortality, egg quality, and gross return per $metre^2$ cage floor area.

By expanding existing cage areas by partial partition removal, the results indicate that there may be welfare advantages for the hens in having more choice as to the area of the cage they could access at any time. Such a move would create an added welfare advantage in that there would be three watering points available in every cage if nipples or cups are used at no extra cost due to the current code provisions. If trough drinkers were in use, then there would be access to a longer length of water trough space which means more hens could choose to drink from the trough at any one time.

The beneficial effects of extra water access in modified cages could be significant under Australian summer conditions in semi controlled environment layer houses. All treatments at the lowest stocking density had poorer food conversion, ate more feed, and became more obese which could lead to fatty liver problems towards the end of lay particularly during Australian summer months. Obese hens are the first to die in sudden onsets of hot weather.

Cannibalism through vent ‘peck out’ in this experiment occurred in only two hens, both from the double cage low stocking density treatment (T3). The level would probably have been considerably higher if the hens had not been beak trimmed. The highest mortality (mainly Mareks disease) occurred in the double cage low stocking density treatment (T3) which suffered the greatest amount of feather pecking and was thought to be at least partially stress induced. The best feather condition at the end of lay was in hens in treatment T2 (two hens/single cage) which demonstrated the value of small group size in terms of plumage protection. If the shed environmental conditions are warm, then replacement of lost and damaged feathers does not proceed as it might otherwise do if the hens needed their feathers for insulation against cold conditions.

If legislation were enacted to force a greater cage floor area per hen which would mean a greater feed trough length per hen, diets would require to be reformulated to allow for the expected higher consumption. If the Australian Code of Practice (Domestic Poultry) was adjusted to meet the current European Economic Council Poultry Directive 88/166/EEC which specifies a minimum of 450 cm^2 per hen for four or more hens in cages and a minimum of 550cm^2 per hen for three hens in cages, then it would be both feasible and economically sound to partially remove existing partitions between 30cm wide x 45cm deep cages and maintain present stocking densities per shed. The partial removal of partitions would not interfere with current door openings and would maintain cage and floor strength if the 1/3 partition were kept at the front of the cage.

Even though the egg size, egg numbers, and egg quality were better on average for the low stocking density groups compared to the higher density groups, the sheer volume of production generated from the latter hens means that the producer will generate a much better return on investment by housing his stock at the current (higher) density. A further consideration for most partially controlled environment egg laying sheds is that if stocking density was reduced in Australia there would be a reduction in the body heat generated which is used to maintain shed (hen) warmth in winter. This could have significant welfare implications on many farms.

Net returns per square metre of cage floor space were in the order of 25% less for the low stocking density treatments compared to those of the high stocking density groups. If the producer cannot see positive welfare benefits for his stock by adopting lower stocking densities, then it will be difficult to obtain industry support for a change to a lower stocking density. Even if welfare benefits were demonstrated, it would also be difficult to convince lending institutions that more money should be invested into the enterprise for welfare purposes if production and hence return to investment is not improved.

Cage enrichments (e.g. the ability to peck at balls or other objects of interest (Rudkin, 1998), and perhaps choice feeding including unmilled grain or coarse chopped hay or roughage (Cumming, 1986) may prove successful in reducing boredom vices such as feather pecking and cannibalism whether or not stocking density were legislatively reduced, and further research should be conducted into these management / husbandry aspects.

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