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& DEVELOPMENT CORPORATION

The Relationship Between Calcium Nutrition, Appetite, Growth, Production and Skeletal Development in Early Egg Production

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FOREWORD

A vexing problem currently facing the egg industry in Australia is the problem of low growth rates and inappropriate appetites of hens housed in controlled environment shedding. These problems represent a major constraint on the ability of the egg industry to achieve optimum egg production, and the problem is most noticeable between the onset of production and peak production (20-30 weeks of age). Daily feed consumption in problem flocks is consistently 13-15% below the breed standards and average body weight has been recorded to decline by 50-100 grams between 20-22 weeks of age and 26-28 weeks of age. The reasons for the weight loss and tissue catabolism in early lay seem likely to be a lag in the appetite response, with appetite inappropriately synchronised with production.

Summers (1983) has suggested that pullets with minimum nutrient reserves at sexual maturity are unable to meet the high demand for nutrient output required by high egg production and body maintenance. As a result body weight gain suffers at the expense of production. Furthermore, Leeson (1990) has also described similar problems of low appetite at peak production, weight loss and a marked post-peak slump in egg production. It seems likely therefore that appetite responses in commercial flocks may vary in early egg production, and that this may interact with the drain of production to produce weight loss and diminished production.

In the face of these growth and production problems in commercial flocks, experimental models need to be established which examine flock growth rates and appetite patterns in a more controlled manner. This research report examines the relationship between body weight, feed intake, calcium nutrition, egg production and skeletal calcium content in three experiments using imported brown egg layers. The research also aims to evaluate the body weight standards provided by the international breeding companies in relationship to the appetite and growth problems identified in Australia.

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EXECUTIVE SUMMARY:

Low appetite and the inappropriate synchronisation of appetite with early egg production is restraining the performance of brown egg layers housed in controlled environment conditions in Australia. In the face of these problems experimental models need to be established which examine flock growth rates and appetite patterns in a more controlled manner. The present research program examines the relationship between body weight, feed intake, production and skeletal calcium content in four studies using imported brown egg layers.

The four experimental models developed in this research project have validated the critical significance of flock growth rates in early egg production (22-30 weeks of age) and have indicated that a normal physiological balance can only be achieved if appetite patterns are effectively synchronised with both growth and production. It is critical that the Australian Egg Industry develops the managerial skills to farm consistently at the genetic/physiological equilibrium described by the breeders. Deviations from this equilibrium can be expected to seriously compromise both production and bird welfare and the tolerance of modern strains to these deviations is likely to be progressively declining.

As a simple managerial measure the production of heavier pullet flocks appears to ameliorate some of the appetite problems, but the problem of appetite responsiveness is a more fundamental question than tissue reserves and body weight. In Experiment 1 there appears to be some degree of genetic susceptibility to lower appetite responsiveness which is probably interacting with management factors. The genetic susceptibility in a proportion of the brown egg layers may be able to be surmounted if the right management factors can be identified. It is clear however that a sudden adaptation to high dietary calcium is not the critical determinant in regulating an appropriate appetite response.

The results achieved in the second experiment with the Lohmann brown birds clearly indicate that appetites can be stimulated in the critical period, resulting in adequate growth rates and production at maximum biological potential (in excess of 100%). The most obvious factors that may be correlated with the more effective appetite response were a period of rapid compensatory growth between 13 to 18 weeks of age and a relatively constant plane of dietary energy density in the transition between grower and layer diets.

To test this hypothesis an experimental model (Experiment 3) was established using pullets that had been subjected to advanced early rearing in the first 8 weeks of life and then a period of significant feed restriction (skip a day feeding) between 8 to 16 weeks of age. The restriction of feed intake appeared to produce a persistent stimulus to appetite in the critical period between 16 to 19 weeks of age. This stimulation of appetite appears correlated with an enhancement of production. This experiment indicated that appetite patterns could be conditioned in pullets and that these techniques can be used to achieve a better synchronisation of appetite with growth and production in sister commercial flocks.

It is clear however, that the successful adoption of these managerial approaches is dependent on a sophisticated understanding of pullet management and that the adoption of these approaches needs to be carefully implemented on individual farms if the outcomes are to be assured.

The sequential studies of skeletal calcium contents (femur calcium) consolidate some standards which can be used to interpret the extent of the peak skeletal calcium reserves that occurs at about 30 weeks of age, and the extent of the skeletal calcium depletion that occurs in mid-lay (40-45 weeks of age). The extent of the skeletal calcium mining in mid lay appears strongly correlated with the severity of osteoporosis. It seems likely that the size of the skeletal calcium pool and the level of depletion in the post peak period will have important effects on persistency of production and the incidence of either clinical or sub-clinical cage layer fatigue. More research is needed on both osteoporosis and on cage layer fatigue because of the production and welfare consequences of these diseases.

1. PROJECT OBJECTIVES:

1. Examine the role of dietary calcium levels in altering both appetite patterns and growth rate of layers in early egg production.
2. Investigate the effects of altered dietary calcium levels on skeletal calcium reserves and skeletal density.
3. Study the effects of the altered growth rates and tissue reserves in layers on peak egg production and persistency of production.
4. Develop management strategies to achieve more precocious egg production in imported brown egg layers.

2. EXPERIMENT 1: *The effect of different calcium regimes on production characteristics*

Introduction

It has recently been hypothesised that additive or synergistic effects of appetite/growth may be achieved by lowering dietary calcium levels in early egg production. More specifically the hypothesis suggests that the use of high dietary calcium (3.5 - 4%) in the early laying phase depresses appetite. If the transition from a grower (1% calcium) to a layer diet (3.5% calcium) occurred more progressively than is currently practised, then both appetite and growth may be further enhanced. If these modifications to calcium nutrition are to be adopted to stimulate flock growth, appetite and performance, it will be important to ensure that skeletal development of birds is not compromised.

This experiment was designed to examine more closely the effect of dietary calcium content in early egg production on appetite, body weight, production and skeletal calcium content.

Materials and Methods

96 Hi-sex laying hens (raised in cages) were purchased from a leading commercial egg producer at 16 weeks of age and placed in 4 banks (2 tiered) of 12 two bird cages. The birds were kept in an environmentally controlled room with temperatures varying between 16-26^{o}C with an average between 20-22^{o}C. All birds were initially fed a commercial pre-lay diet containing 1% calcium. At 19 weeks of age birds were split into two treatments, one treatment receiving 3.5% dietary calcium throughout the trial, while the other birds received 2.2% dietary calcium to 24 weeks, 2.5% calcium to 28 weeks of age and then 3.5% calcium until 40 weeks of age. Both diets had a ME value of 11.6 MJ/kg and a crude protein value of 17.9% and were identical apart from the calcium levels. All birds had water and feed available *ad libitum.*

Egg production per cage was recorded each day of the experimental period and accumulated to provide weekly figures. Birds were weighed as a cage at two week intervals until 28 weeks of age, after which they were weighed at 31, 34, 36 and 39 weeks of age. Each cage had feed weight recorded allowing subsequent calculation of feed consumption. Feed consumption was calculated at 22, 26, 33 and 39 weeks of age. Twenty birds from the same flock, additional to the 96 in the trial, were humanely killed prior to the start of the trial and had their left femur removed and frozen for subsequent analysis of calcium concentration.

At the end of the trial period (40 weeks of age) all birds were humanely killed and an assessment of the costochondral junction of the rib cage made to estimate the incidence and severity of osteoporosis (Table 1). In addition twenty birds from each of the 2 calcium treatments had their left femur removed for femur calcium content determination. A post mortem examination was carried out on each bird that died during the experimental period.

Table 1: Abnormalities of the costochondral junction and severity index score

Score	Description
0	No nodular lesion of costochondral junction
1	Detectable lesion at junction
2	Marked nodular lumps
3	Marked nodular lumps and some bending or infolding of ribs
4	Large nodular lumps, significant infolding or deformation of the ribs
5	Large nodular lumps and gross deformation of the rib cage

Calcium Assay

The concentration of calcium contained in poultry bone samples was determined using atomic absorption spectrophotometry.

Results

There was no significant difference between the two calcium treatments in terms of body weight (Figure 1), egg production (Figure 2) or feed consumption. Consequently all results, excluding femur calcium data, have been combined regardless of calcium treatment.

Figure 1: Average body weight of each calcium treatment (■ - 3.5% calcium, ● - 2.2% calcium)

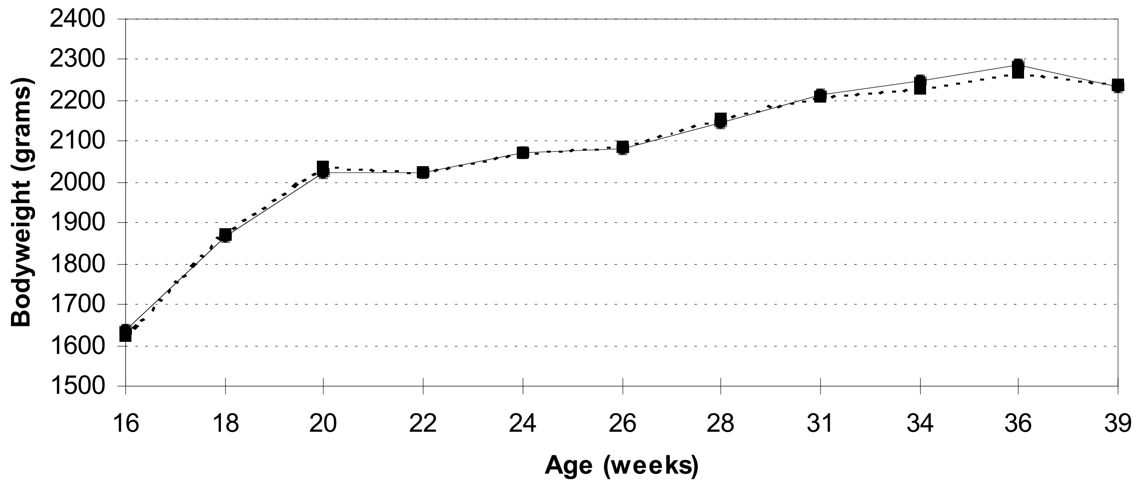
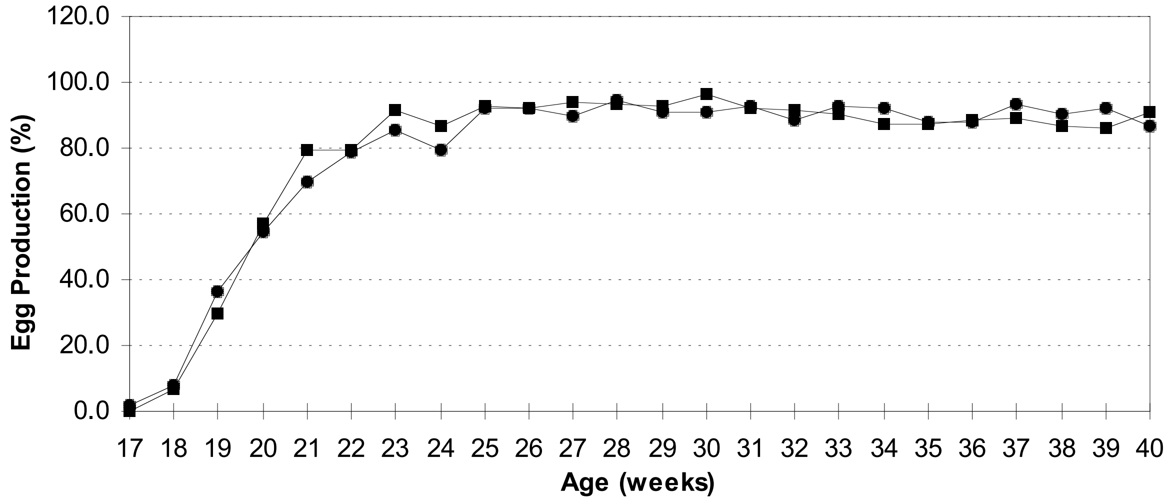


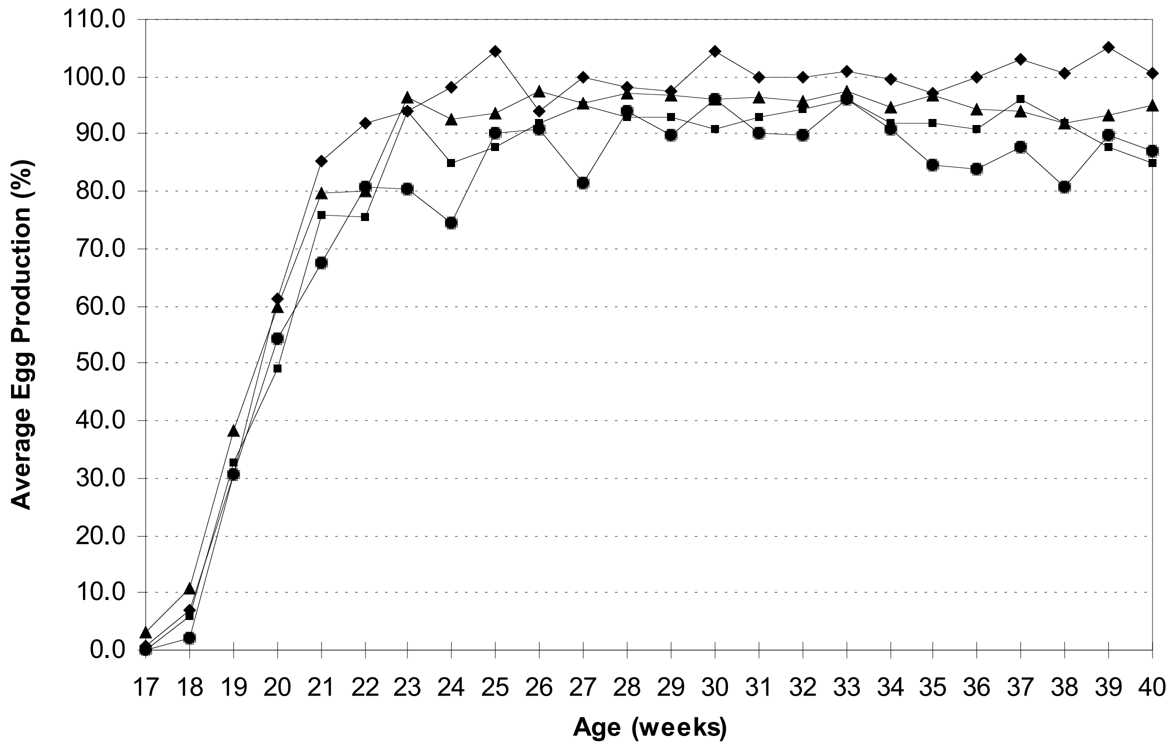
Figure 2: Average egg production of each calcium treatment (■ - 3.5% calcium, ● - 2.2% calcium)



Flock Production Stratification

The whole flock was stratified into production groups for the period between 21-40 weeks of age. The groups were ranked as producing at 96%+, 92-96%, 88-92% and 84-88%, with each production group containing 28, 28, 14 and 14 birds respectively. These groups were then analysed for egg production, growth rate and feed consumption.

Figure 3: Average egg production of birds in each of four groups based on egg production from 21-40 weeks of age (● - 84-88%, ■ - 88-92%, ▲ - 92-96%, ♦ - 96%+)



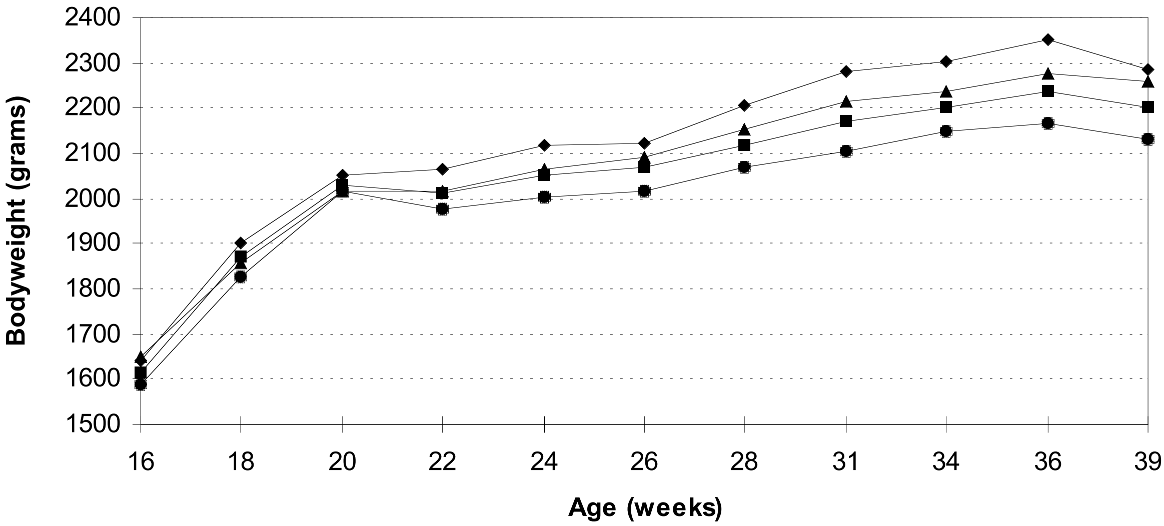
Egg Production

The 96%+ groups egg production peaked at 25 weeks, 92-96% peaked at 26 weeks, 88-92% group peaked at 33 weeks and the 84-88% group peaked at 30 weeks (Figure 3). The respective peaks were 104.5, 97.5, 96 and 96%. There is a significant difference between the highest (96%+) and lowest laying group (84-88%) ($P<0.01$).

Body weight

The lowest producing group has the lowest body weight at 16 weeks of age, while the highest producing group is approximately 50 grams heavier at the same age. The differences in pullet weight were not significant. All 4 groups increase linearly in weight up until 20 weeks of age. From 20 to 22 weeks of age all groups except the 96%+ group lost weight, while the 96%+ groups weight plateaued (Figure 4). From 22 to 36 weeks of age body weight increased linearly in all groups. From 36-39 weeks weight dropped in all groups, especially in the highest production group (Figure 4). There is a strong correlation between the production of the birds and body weight, with the higher producing birds having higher body weights. There is a significant difference in body weight between the highest and lowest laying groups ($P<0.01$).

Figure 4: Average body weight of birds in each of four groups based on egg production from 21-40 weeks of age (● - 84-88%, ■ - 88-92%, ▲ - 92-96%, ♦ - 96%+)

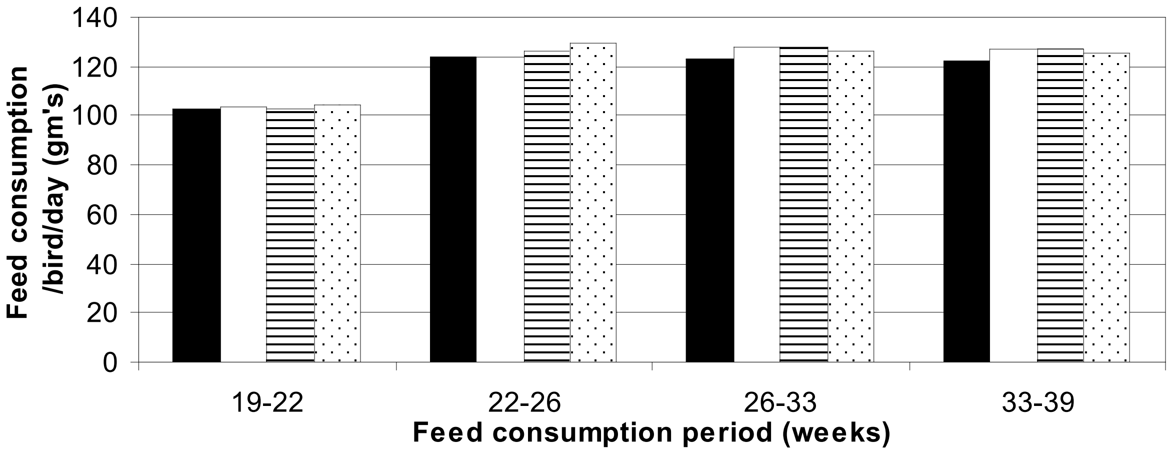


Feed Consumption

Feed consumption increased significantly ($P<0.05$) (20-24 grams/bird/day) between the first (19-22) and second period (22-26 weeks), and is correlated with the rising plane of production. In these periods the high egg production group (96%+) increased feed consumption from 105 to 129 grams/day, whilst in the low egg production group (84-88%) feed consumption increased from 103 to 124 grams/day (Figure 5). This lower appetite response appears correlated with the lower gain in body weight and the lower overall production performance of the smaller birds (Figures 3, 4).

Overall there was a significant difference in feed consumption between the highest (96 %+) and the lowest (84-88%) laying groups over the experimental period ($P<0.05$) (Figure 5) which appears strongly correlated with the different growth patterns.

Figure 5: Feed consumption of birds for four time periods in each of four groups based on egg production from 21-40 weeks of age (■ - 84-88%, □ - 88-92%, ▤ - 92-96%, ░ - 96%+)



Estimated Incidence of Osteoporosis and Femur Calcium

Both calcium treatment groups had a similar incidence of osteoporosis with 49% of birds affected (score 1-5), and 5% of birds severely affected (score 3-5).

Table 2: Average femur calcium content at 16 and 40 weeks (20 birds per sample, standard error given in parenthesis)

Age (weeks)	Treatment	Femur Calcium Content (gram's)
16	NA	0.75 (0.02)
40	3.5% Ca	1.03 (0.04)
40	2.2% Ca	1.03 (0.04)

There is no difference between the two calcium treatments in femur calcium content at 40 weeks of age (Table 2), or in the incidence of rib cage abnormalities. The femur calcium levels are higher at both 16 and 40 weeks of age in these birds compared to previous research, and this is probably a reflection of the higher body weights of these birds and a lower severity of osteoporosis.

Discussion

There was no difference in any of the parameters measured between those birds fed either dietary calcium regime (mash diets). It is apparent therefore, that high dietary calcium in early lay is unlikely to be contributing to the depression in growth and feed consumption observed in many Victorian flocks. As an experimental model the flock achieved very high levels of production, and satisfactory growth rates in early lay. The current trial was established using pullets with body weights that exceeded the breeder standards by about 10-12%.

The stratification of the flock performance into four groups ranging from almost 100% to 86% production illustrated a strong correlation between the birds body weight and production. The critical time period for these shifts in body weight was between 20 and 22 weeks of age. In the highest producing birds (96%+) growth plateaued, while other less productive birds (86%) lost weight. Both prior to 20 weeks and following 22 weeks growth patterns between the four groups of birds are reasonably linear.

Egg production in the stratified groups appears to be determined by 3 factors, 1) the amount of weight lost in the period 20-22 weeks of age, 2) the appetite response in the period 22-26 weeks of age and 3) the weight of the bird at point of lay. The birds in the two high producing groups (96%+, 92-96%) increased their appetite during the period 22-26 weeks of age by 24 grams/day, whilst the birds in the two low producing groups (84-88%, 88-92%) increased their appetite by approximately 21 grams. Even the small difference of 3 grams feed/day may be significant in determining long term productivity. Although not significant, it was apparent that at 16 weeks of age the lowest producing birds were the lightest birds while the highest producing birds were the heaviest birds.

For purposes of economic evaluation the highest producing birds in the experimental model had an average egg production of 98% (21 to 40 weeks), with a body weight of about 2.3 kg @ 36 weeks of age and an average feed consumption of 122 grams/bird/day. The poorest egg production group averaged 86% production, with a live weight of 2.15 kg and an average feed consumption of 119-120 grams/day.

Many of the hypotheses formulated during on-farm studies about the shifts in flock growth patterns and the link to productivity have been substantiated in this experiment.

Clearly the findings in this research are difficult to reconcile with breeder recommendations suggesting much higher levels of productivity in smaller birds (1.9-2.0 kg @ 36 weeks of age). The lag in the appetite response in early lay appears a persistent problem even in pullets/layers that have body weights that exceed the breed standards by 10-12%.

3. EXPERIMENT 2: *Comparison of Two Laying Strains with Markedly Different Body Weights and Metabolic Balances*

Introduction

The aim of the current experiment was to study the effects of a high metabolic drain on the appetite response in early lay in a novel laying strain, with high egg mass in relationship to body weight and tissue reserves. Additionally, the novel strain was assessed against a commercial strain for egg production, body weight, feed consumption, femur calcium content and osteoporosis score.

Materials and Methods

The strains used were a tinted egg layer and a commercial Lohmann brown. Both the tinted bird and the Lohmann brown bird were raised in litter based environments, albeit on a different property, until 13 weeks of age. At 13 weeks of age 58 birds were selected from each group, of which 48 were placed into 2 bird cages at a research facility. The remaining 10 birds from each group were humanely killed and their left femur removed for subsequent analysis of calcium content.

The birds were kept in an environmentally controlled room with temperatures varying between 16-26^{o}C with an average between 20-22^{o}C. All birds were fed a commercial broiler grower ration (ME 12.1 MJ/kg and crude protein 18%) until 19 weeks of age, followed by a commercial layer diet (purchased from a local producer) for the remainder of the experimental period. The layer diet had a ME value of 11.6 MJ/kg, a crude protein value of 17.9% and contained 3.5% calcium. Feed and water were available *ad libitum.*

Birds were weighed as a cage at two week intervals, starting at 17 weeks of age and continuing throughout the experimental period. In two bird cages body weight was halved to provide average bird weight. Egg production per cage was recorded daily and accumulated to provide weekly figures. Egg weight was calculated weekly (all eggs from a particular day were weighed). After 20 weeks of age all feed was weighed before being placed into feed compartments (covering 2 cages) thus allowing the subsequent calculation of feed consumption per two cages. Feed consumption was averaged between the number of birds having access to each feed compartment. Feed consumption was calculated at 23, 51, 100, 127 and 169 days after the commencement of feed weighing. A post mortem examination was carried out on each bird that died during the experimental period.

At the end of the experimental period (45 weeks of age) all birds were assessed for osteoporosis by palpation of the costochondral junction of the rib cage. Additionally, 20 birds from each strain had their left femur removed for subsequent determination of femur calcium.

Flock Stratification

Production and body weight in the Lohmann brown flock was stratified into two groups based on whether they lost weight in the period between 27 and 29 weeks of age. In a separate analysis the Lohmann brown flock's production and body weight was stratified according to the severity of osteoporosis, which was assessed at 45 weeks.

Calcium Assay

The same technique was used as in Experiment 1.

Results

Body Weight

At 13 weeks of age the average body weight of the 2 strains of birds was 991 and 889 gram's for the Lohmann's and tinted bird respectively. At all measurement points from 17 through to 45 weeks the average Lohmann brown body weight was significantly higher than the tinted bird ($P<0.01$) (Figure 6). At 45 weeks of age the average Lohmann brown weight was 2079 grams while the tinted bird had an average weight of 1641 grams. Average body weight of the trial Lohmann's was higher than that of the Lohmann brown standard, except between 26 and 32 weeks of age. The tinted bird was significantly smaller ($P<0.01$) than a standard Lohmann white Leghorn. There was a plateau in weight gain in the Lohmann brown birds between weeks 28 and 30, while the tinted birds experienced a period of weight loss during the same period. There was also a plateau in weight in the tinted bird between weeks 24-26. The period of weight loss occurred in the Lohmann's just after peak egg production, while the tinted birds experienced a plateau in growth just prior to and a period of weight loss immediately following peak egg production.

Figure 7 illustrates the body weight comparison between the Lohmann brown birds that lost weight between 27-29 weeks of age and those that did not. It is clear that the birds that lost weight during this period were not able to compensate for this diminished growth and remained lighter for the duration of the experiment.

Figure 6: Average body weights of each trial strain (Lohmann's - ■, tinted layer - ▲, Lohmann White Leghorn standard - ● and Lohmann brown standard - ♦).

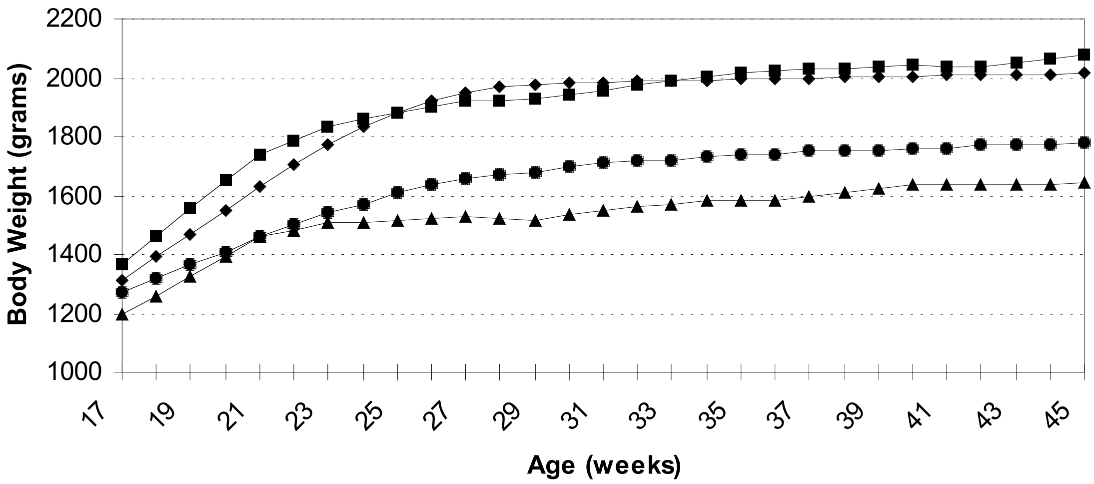
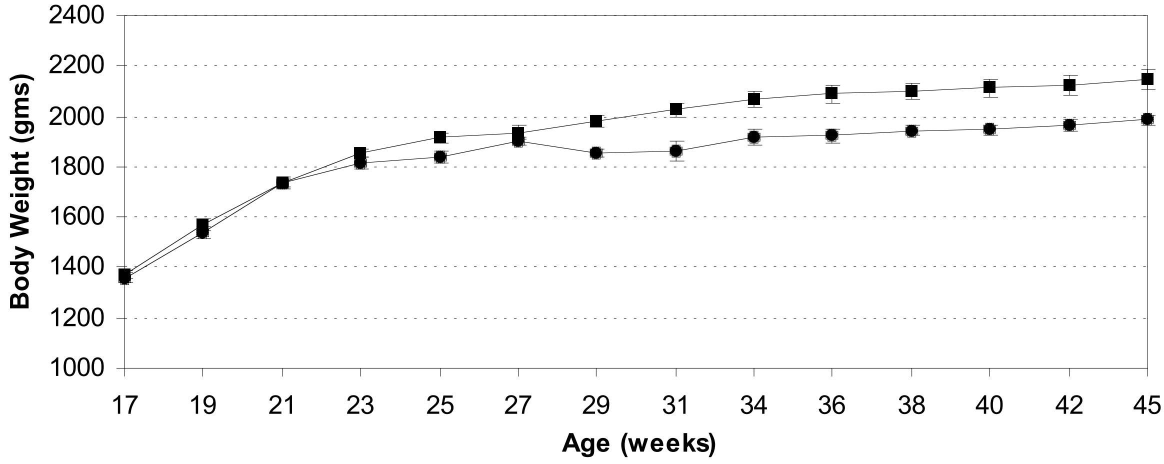


Figure 7: Comparison of body weight between the Lohmann brown birds that lost weight between 27-29 weeks (●) and those that did not (■) (standard error given).



Egg Production

The Lohmann brown bird's production was superior to the tinted bird's production (significant ($p<0.05$) at 28, 29, 32, 33, 34, 35, 36, 37, 39, 41, 42 and 43 weeks) in all weeks after week 25 (Figure 8). This result is not surprising considering the exceptional performance of the Lohmann browns. The Lohmann's peaked at 99% in week 28 and maintained production at over 93% from week 25 until the end of the experimental period (Figure 8). Lohmann brown production was in excess of the Lohmann brown standard at all measurement points.

The tinted layer peaked at 97.5% in week 26 and fluctuated between 87 and 94% from week 27 until the trial's end. During weeks 27 to 29, a period where the tinted birds lost weight, there was a concurrent decrease in the tinted layers egg production. Production also decreased between weeks 34 to 37 which corresponds to another plateau in body weight. This period is likely to coincide with the demands of peak egg mass.

Figure 9 illustrates the effect of weight loss during weeks 27-29 on the production performance of the Lohmann brown birds. The group that lost weight during 27-29 weeks had a marked drop in production between weeks 28 to 33. After week 33 the birds in the 2 stratified groups laid at a similar rate. The post peak decline in body weight of some of the Lohmann brown birds was clearly associated with the loss of production that persisted for only a few weeks.

Figure 8: Average production of each trial strain (Lohmann's - ■, tinted layer - ▲) and the Lohmann brown standard (◆).

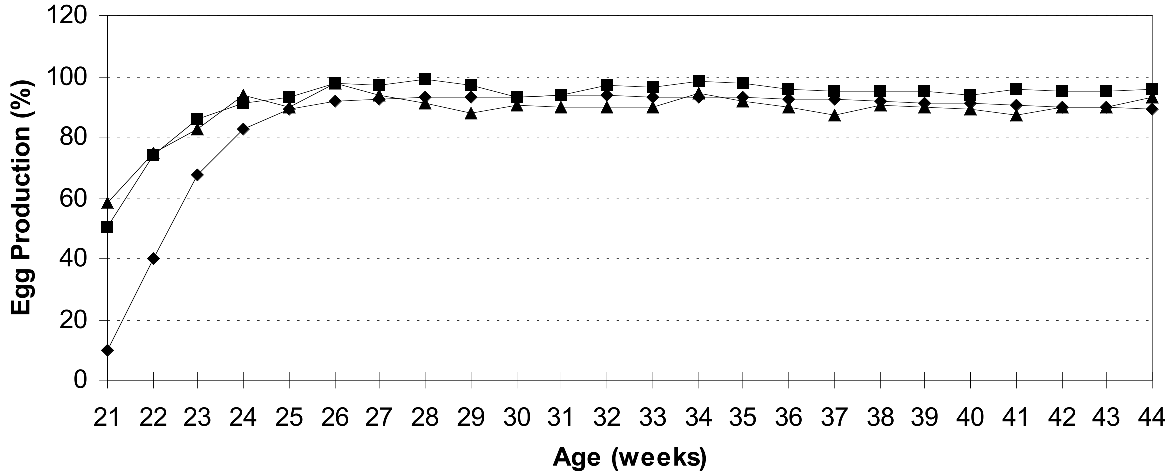
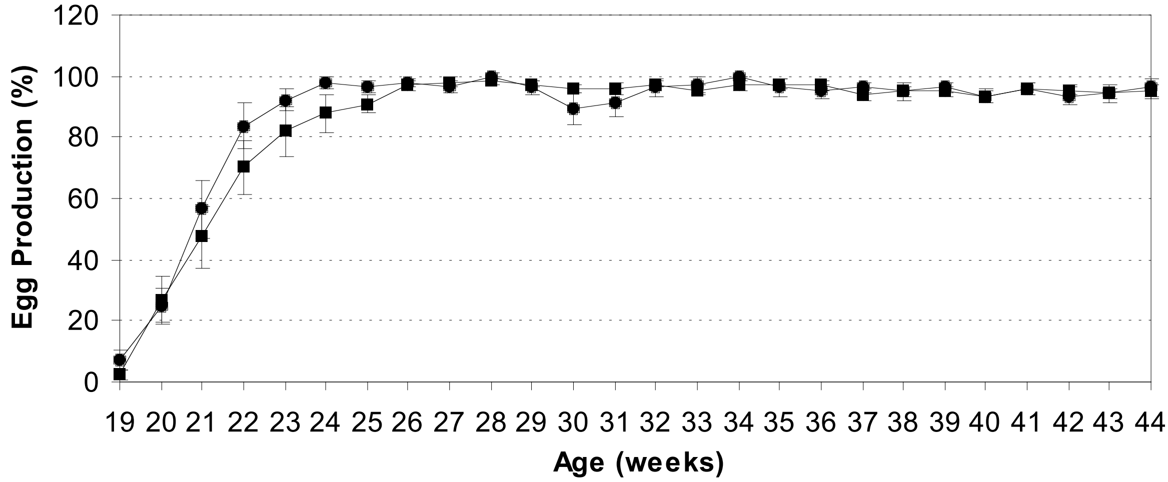


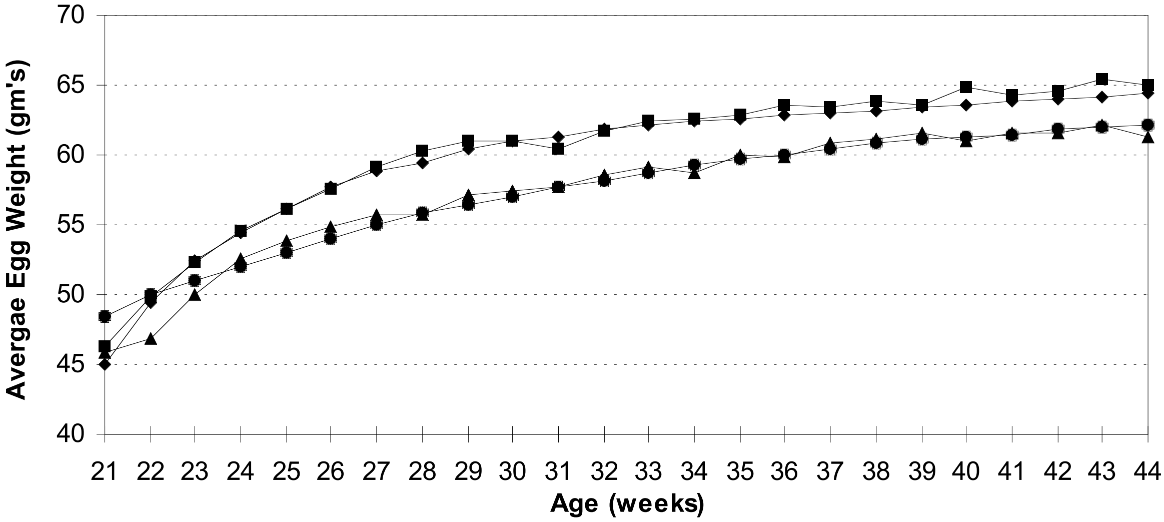
Figure 9: Comparison of production between those Lohmann brown birds that lost weight between 27-29 weeks (●) and those that did not (■) (standard error given).



Egg Weight

The egg weight of the Lohmann brown bird was significantly higher than that of the tinted bird (Figure 10) over the experimental period. There was no significant difference in egg weight between the Lohmann brown standard and the trial Lohmann brown birds. From 22 weeks until the end of the trial, egg weight of the tinted layer was between 2 to 4 grams lighter than the Lohmann brown bird. Interestingly egg weight of the tinted bird was remarkably similar to the Lohmann White Leghorn despite its lower body weight. The average egg weight to body weight ratio was 3% in the Lohmann brown birds and 3.5% in the tinted birds over the experimental period.

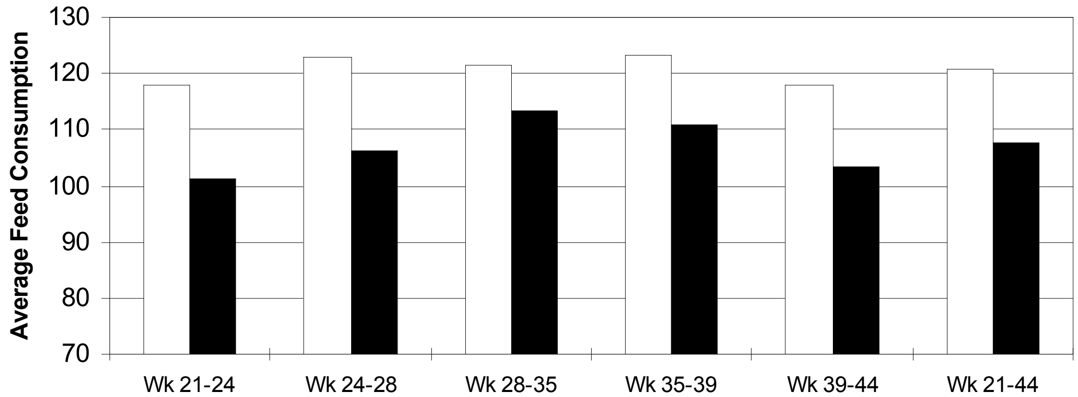
Figure 10: Average egg weight of each trial strain (Lohmann's - ■, tinted layer - ▲), White Leghorn standard (●) and Lohmann brown standard (♦).



Feed Consumption

In each period examined there was a significant difference in feed consumption between the two strains of birds ($P<0.01$ for weeks 21-24, 24-28, 35-39, 39-44 and $p<0.05$ for weeks 28-35). Average feed consumption from week 21 to 44 was 120.6 and 107.5 grams/bird/day for the Lohmann's and the tinted bird respectively (Figure 11). Over the experimental period the tinted birds consumed 10.9% less feed than their Lohmann brown counterparts after figures were adjusted for bird numbers.

Figure 11: Average feed consumption (grams/bird/day) of each strain (Lohmann brown - □, tinted layer - ■)



Egg Mass, Feed Intake and Body Weight

The Lohmann brown birds produced about 3% more eggs than the tinted egg layer, and had an average egg weight that exceeded the tinted egg layer by 5.6% (62.3 versus 58.8 grams). The Lohmann brown birds had an egg mass output that exceeded the tinted egg layer by 9.2%. The tinted egg layer however was 20% smaller and feed consumption was reduced by 10.9% in comparison to the Lohmann brown. The egg weight to body weight ratio of the tinted egg layer was 3.5% compared to 3% in the Lohmann brown.

Clearly the metabolic drain on the tinted egg layer exceeded that experienced by the Lohmann brown and this model is likely to reflect some of the future advancements that can be expected in egg laying stocks with inputs reduced and outputs increased.

Estimated Incidence of Osteoporosis and Femur Calcium Content

Table 3: Average femur calcium content at 13 and 44 weeks (20 birds per sample, standard error given in parenthesis)

Age (weeks)	Strain	Average Femur Calcium Content (gram's)
13	Lohmann brown	0.35 (0.02)
	Tinted layer	0.43 (0.02)
45	Lohmann brown	0.86 (0.04)
	Tinted layer	0.71 (0.03)

At 45 weeks of age the incidence of osteoporosis, as assessed by palpation of the costochondral junction of the rib cage, was 57% in the Lohmann brown birds and 33% in the tinted birds, with 29 and 13% of birds severely affected in each strain respectively.

There was a significant difference ($P<0.05$) between the two strains in femur calcium content at 14 weeks of age, and again at 45 weeks of age ($P<0.01$). This is most likely due to the difference in body weight between the two groups (the Lohmann's averaged 889 and 2079 gram's for the two periods versus 991 and 1641 gram's for the tinted bird).

Comparing the two strains indicates that the small tinted layer with the high egg mass output in relationship to body weight is no more susceptible to osteoporosis than the Lohmann brown bird, and in fact may be more resistant.

Stratification of flock body weights and production in the Lohmann brown birds based on the severity of osteoporosis

Figures 12 and 13 illustrate the relationship between osteoporosis score, based on palpation of the costochondral junction of the rib cage, and body weight and production. Birds that scored 3 or greater were subjectively assessed as having severe osteoporosis, while birds with a score between 0-2 were assessed as having only slight or no osteoporosis (for descriptions see Experiment 1, Table 1). The differences between the two groups are extremely similar to those differences seen between the groups that were stratified according to weight changes between 27 and 29 weeks. The results indicate that, as expected, those birds which experience body weight loss near peak egg production are more susceptible to osteoporosis, and are also likely to produce fewer eggs.

Figure 12: Average body weight comparison between birds that had severe osteoporosis at 45 weeks of age (●) and those that were not affected or only slightly affected (■) (standard errors given).

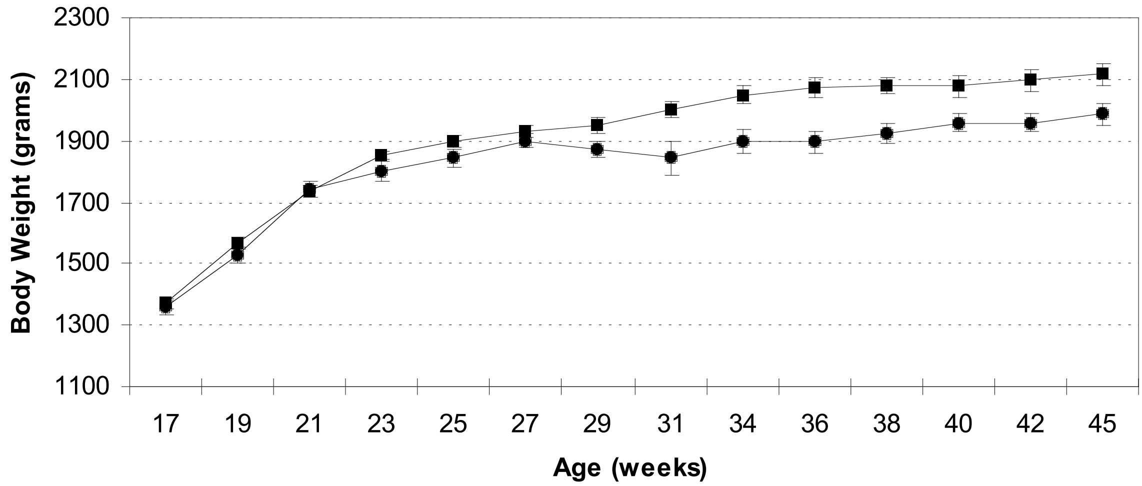
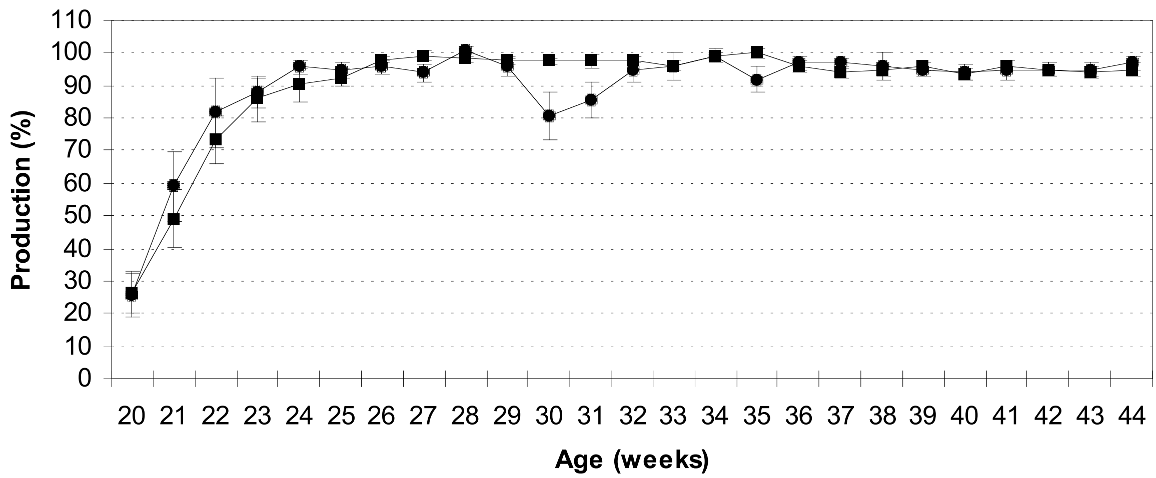


Figure 13: Average egg production comparison between birds that had severe osteoporosis at 45 weeks of age (●) and those that were not affected or slightly affected (■) (standard errors given).



Cage Layer Fatigue

At 23-24 and 28 weeks of age 8% of the tinted layers experienced a form of paralysis similar to cage layer fatigue. About 4% of the Lohmann's exhibited similar symptoms between 27-29 weeks of age. A period of weight loss appeared to precipitate the paralysis symptoms, and eventually the birds ceased egg production. After 1 to 2 weeks the birds regained mobility and body weight and resumed laying at previous rates. A post mortem of 4 clinically affected tinted birds illustrated significant infolding of the rib cage and very low femur calcium content (in comparison to normal birds), both symptoms characteristic of osteoporosis.

The development of the clinical paralysis symptoms appears strongly correlated with the periods of weight loss in both strains.

Dry Shell/Egg Weight Percentage

Dry shell weight divided by egg weight expressed as a percentage was 9.41 in the tinted birds and 9.04 in the Lohmann's. This measurement was taken at 45 weeks of age.

Discussion

As was expected the tinted bird had a significantly lower body weight than the Lohmann brown bird at all measurement periods. The average body weight at 45 weeks of age was 1.64 kg, which is approximately 160 grams smaller than the Lohmann White Leghorn. The smaller bird provides an effective model to illustrate the consequences of the metabolic drain, and the increased managerial sensitivity of smaller, more feed efficient commercial layers. Furthermore, this tinted egg layer is likely to reflect the managerial problems that may arise in the Australian egg industry when the small US White Leghorn lines are introduced into Australian systems.

This experiment highlighted the exceptional performance capacity of the Lohmann brown bird and these results were unexpected considering that the birds were underweight at 13 weeks of age. Clearly the brown egg layers have some degree of robustness, given compensatory growth between 13-17 weeks of age and an appropriate appetite response in early lay. More importantly, the Lohmann's did not experience a period of weight loss (tissue catabolism) prior to peak production. Clearly the growth curves and appetite patterns described in the breeder manuals can be attained under Australian conditions. It is interesting to note that the rate of growth plateaus between 27-30 weeks of age, but not to the extent of weight loss.

The main difference between this experiment and other studies is that feed intake was at accepted standards (118 grams/bird/day) in the period between 21-24 weeks of age in birds with a moderate body weight (1.7-1.8 kg). Feed intake appeared to be stimulated well in advance of high productive demands.

Genetic advancement in the egg industry is decreasing the size of commercial laying stocks whilst retaining a large egg mass output. It has been hypothesised that the incidence and severity of osteoporosis will increase as a consequence. This model provided an opportunity to evaluate this hypothesis by using a strain of birds with a higher egg mass to body weight ratio. Surprisingly the tinted birds were less affected than the Lohmann brown birds at 45 weeks of age, and the severity of the osteoporosis was also lower. This indicates that the tinted bird may have a more efficient calcium metabolism that provides some protection against osteoporosis.

One problem seen in the tinted birds and to a lesser extent in the Lohmann brown birds was the presence of cage layer fatigue like symptoms in early lay (22-29 weeks of age). Clearly some individual birds appear genetically susceptible to cage layer fatigue and the strong correlation of the symptoms of osteoporosis and weight loss in the Lohmann brown birds may provide an approach to select against susceptibility to both cage layer fatigue and osteoporosis.

It is highly likely that this condition is also occurring in commercial operations and may be responsible for pre and post peak production slumps. With the larger numbers of birds in cages on commercial farms it is probable that this problem would go largely unrecognised and contribute to mortality. If the syndrome is observed in commercial flocks it is likely that it could be viewed as Marek's disease, because the clinical symptoms are very similar. It is clear in these studies that the paralysis is transitory if the birds are allowed to recover, but it is conceivable that cage layer fatigue could interact with the expression of Marek's disease in commercial flocks, and is worthy of additional study.

The Lohmann brown birds have lower than expected calcium reserves (0.35 grams @ 13 weeks and 0.86 grams @ 45 weeks) and it seems likely that this may have increased the sensitivity of the flock to cage layer fatigue and osteoporosis. It is evident however, that the smaller skeletal calcium reserves did not compromise the peak production and had only marginal effects on persistency of production. The ability of the birds that developed severe osteoporosis between 27-29 weeks of age to sustain production to 45 weeks was unexpected, and needs to be evaluated in longer term experiments that reach at least 70 weeks of age.

Objective information on skeletal size in commercial layers is being developed from this work and the significance of the skeletal calcium pool to both production and shell quality will be able to be clarified. Many of the older hypotheses regarding productivity and skeletal size may have a strong foundation.

The promising appetite patterns of the Lohmann brown bird seems likely to result from some conditioning effects achieved in the pullet-rearing phase. At the end of this experiment it was hypothesised that the growth suppression at 13 weeks and the compensatory growth achieved thereafter may be the critical factor in the persistence of the appetite response into early lay. To test this hypothesis a third experiment was designed that involved advanced early growth (day old to 8 weeks) and then a period off both feed and growth restriction between 8 weeks and point of lay.

4: EXPERIMENT 3: *The effect of pullet rearing regime on appetite, growth and subsequent production*

Introduction

One of the important questions raised by Experiment 2 was the effect of rearing regime on appetite patterns in early egg production. It was hypothesised that the pullet rearing in Experiment 2 may have contributed to the birds' appetite during early lay, the lack of tissue catabolism and the excellent subsequent production. To further examine this hypothesis a trial was set up whereby a commercial egg producer subjected birds to two rearing regimes. The first treatment was conventional farm practice where the pullet was subjected to an advanced growing regime, particularly from day old to 8 weeks of age. The second regime used the advanced early rearing from day old to 8 weeks of age followed by skip a day feeding from 8-16 weeks. It was hypothesised that feeding the birds every second day between 8-16 weeks would result in a lighter pullet with subsequent benefits on appetite response and compensatory growth in early lay when the birds were returned to an *ad libitum* feeding regime.

Materials and Methods

48 ISA brown birds from each of two rearing treatments (see below) were randomly selected and transferred to an experimental facility at 16 weeks of age. They were placed into two bird cages in a controlled environment shed where the temperature was maintained between 18-25^{o}C, with an average of 20-22^{o}C. All birds were initially fed a commercial pre-lay diet containing 2.2% calcium, 17.5% protein and had an ME of 11.6 MJ/kg. At 19 weeks of age birds were transferred onto a layer diet containing 3.6% calcium, had an ME value of 11.5 MJ/kg and a crude protein value of 18.4%. All birds had water and feed available *ad libitum.*

Treatment 1 – control birds (advanced early rearing) were reared conventionally.
Treatment 2 – as per control birds to 8 weeks of age. Birds were then subjected to skip a day feeding from 8-16 weeks and then returned to a conventional feeding program. The feed allocation provided every second was approximately equivalent to 1.5 day's feed based on *ad-lib* consumption.
(Note: birds were reared in cages in a 20,000 bird shed, with 10,000 birds in each treatment)

Egg production per cage was recorded each day of the experimental period and accumulated to provide weekly figures. Birds were weighed as a cage at two week intervals. Each cage had feed weight recorded allowing subsequent calculation of feed consumption. Feed consumption was calculated at 19, 24, 26 weeks of age. Ten birds from each treatment, additional to the 96 in the trial, were humanely killed prior to the start of the trial and had their left femur removed and frozen for subsequent analysis of calcium concentration.

At the end of the trial period (35 weeks of age) all birds were humanely killed and an assessment of the costochondral junction of the rib cage made to estimate the incidence and severity of osteoporosis. In addition, twenty birds from each of the 2 rearing treatments had their left femur removed for femur calcium content determination. A post mortem examination was carried out on each bird that died during the experimental period.

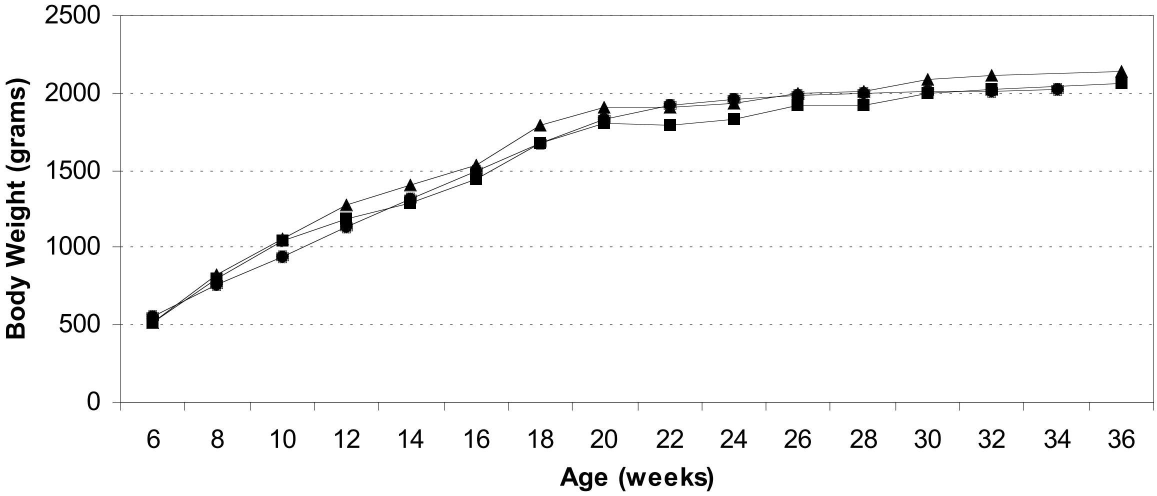
Because the birds were taken from a commercial flock, a comparison between body weight and egg production in the commercial flock was made with body weight and egg production in the experimental flock.

Results

Body Weight

The average body weight of the two groups at 16 weeks of age was 1.45 kg for the restricted group and 1.53 kg for the control group. The difference in body weight between the two treatments became apparent after 10 weeks, and from 12 weeks on the differences between the two lines remained reasonably consistent. Even after the cessation of the skip a day feeding (at 16 weeks) regime and the availability of *ad libitum* feed there is no convergence of body weight. Both groups of birds experience a drop in weight between 20-22 weeks of age. The control pullets had a body weight at 18 weeks of age that was approximately 10% above the ISA standard, while the restricted pullets had a body weight very close to the ISA standard. At 36 weeks of age body weight in the skip a day treatment averaged 2.06 kg while the control group averaged 2.14 kg.

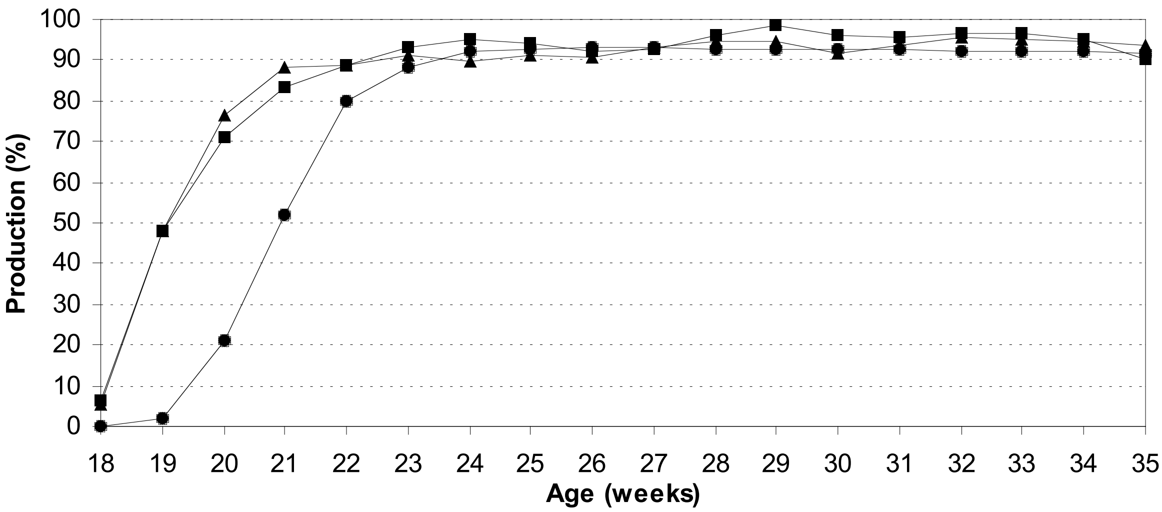
Figure 14: Average body weight of the two rearing treatments along with the ISA standard (● - ISA standard, ■ - skip a day, ▲ - control)



Production

There is no significant difference between the two treatments over the experimental period. Production peaks at 98.7% for the skip a day rearing treating in week 29, while the control treatment peaks at 95.5 in week 32 (Figure 15). Overall the skip a day rearing treatments production is in excess of the control treatment's production by approximately 3-4% (Figure 15). In both treatments production is approximately a week and a half in advance of the ISA standard up until 22 weeks.

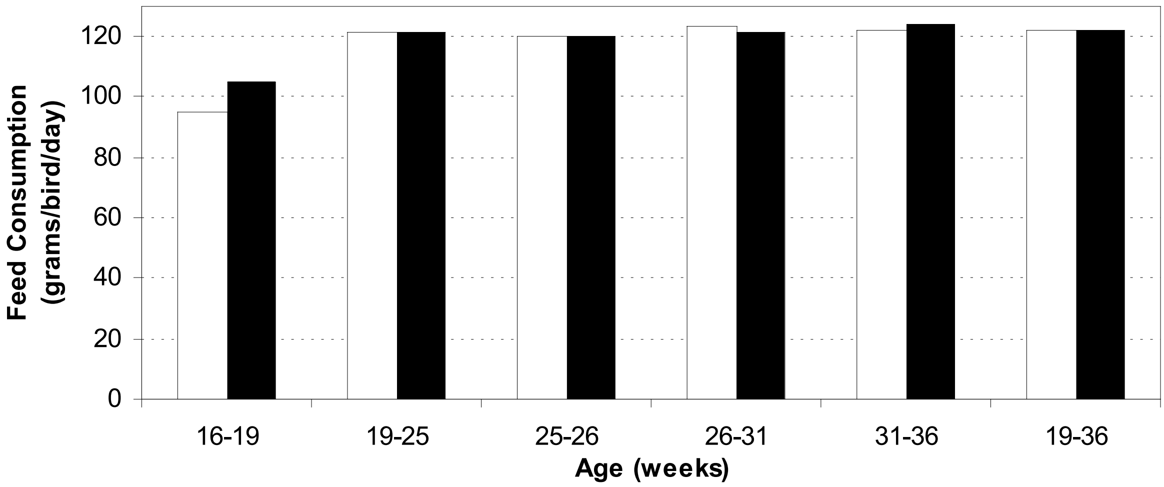
Figure 15: Average production of the two rearing treatments (■ - skip a day, ▲ - control) in comparison to the ISA standard (●).



Feed Consumption

There was a significant difference (P<0.001) in feed consumption between the two treatments for the period between 16-19 weeks of age (pre lay diet), with average values of 104.9 and 94.8 grams/bird/day for the restricted and control groups respectively (Figure 16). Between the weeks of 19-36 average feed consumption was 122 and 121.9 grams/bird/day for the restricted group and control group respectively (Figure 16). No significant differences were seen between the treatments in any measurement period after 19 weeks of age.

Figure 16: Average feed consumption of the two rearing treatments (■ - skip a day, □ - control).



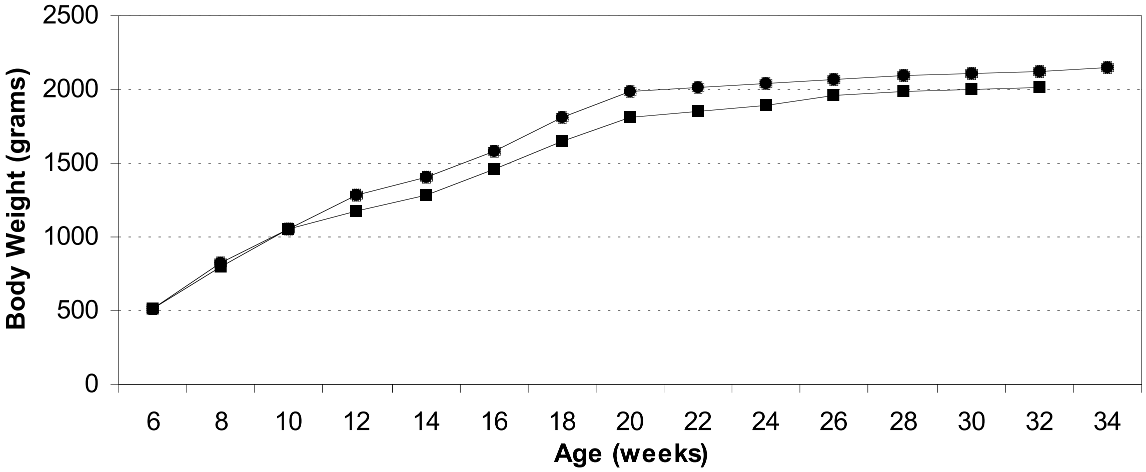
Sister commercial flock

Egg production for the sister commercial flock was determined between 26-29 weeks of age to validate findings of the experimental model (Table 4). A similar improvement in production (3-5%) in the restricted group was seen in the commercial flock. The commercial flock body weights are illustrated in Figure 18, and show similar differences to those seen in the experimental flock.

Table 4: Comparison between skip a day rearing and conventional rearing in the sister commercial flock.

Age (weeks)	Production (%)	
	Skip a day	Control
26	93	90
27	95	90
28	93	90
29	95	89

Figure 18: Average body weights of the two rearing treatments in sister commercial flock (● - skip a day, ■ - control).



Femur Calcium

At 16 weeks of age the average femur calcium content was 0.6 grams in the restricted group compared with 0.62 grams in the control group, a difference of 3%. The difference in body weight at 16 weeks was 5% (1.45 kg versus 1.53 kg).

At 36 weeks of age the average femur calcium content was 1.04 grams in both treatments. The incidence of osteoporosis (score 1-5) was 52% and 49% in the skip a day and control treatments respectively. The percentage of birds severely affected (score 3-5) at 36 weeks was 9% (3 birds out of 33) and 0% in the skip a day and control treatments respectively.

Discussion

The restricted birds achieved a slightly higher production performance than the control group, and provided evidence that the breeder body weight standards can be applied in Australia. For these body weight standards to be effectively applied the appetite of the flock needs to be stimulated effectively in the period between 16 to 24 weeks of age. This experiment provides evidence illustrating that appetite patterns can deviate significantly irrespective of temperature, dietary energy density and body weight.

The 8 week period of feed restriction does not appear to have had a significant impact on flock uniformity, and appears to have produced a relatively persistent stimulus to feed intake once the birds were allowed *ad libitum* access to feed.

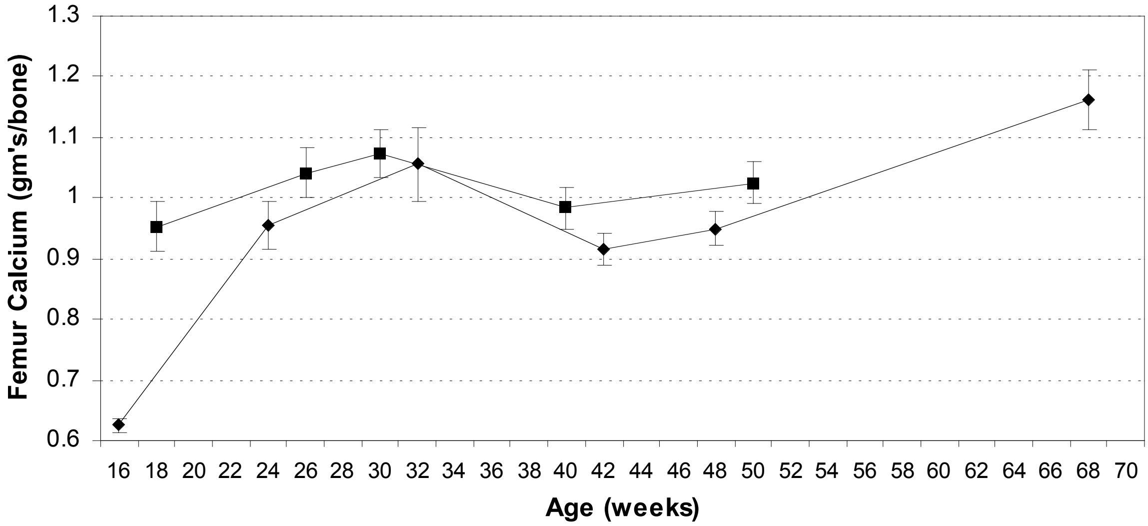
In summary the pullet growth pattern developed involves accelerated early growth followed by a period of quantitative feed restriction and then a period of compensation in early lay. If this model can be applied successfully at a commercial level on other properties the industry can look forward to farming with smaller pullets that match European body weight standards.

5. LABORATORY STUDY: *Assessment of femur calcium content in brown egg layers*

The development of models that objectively define skeletal size and skeletal calcium pools are required to answer some of the hypotheses about the link between skeletal size and productivity, and to study the induction of osteoporosis in the laying hen

In order to develop an objective methodology, the femur calcium contents of two flocks of brown egg layers were sequentially assessed during lay. Each of the flocks showed similar patterns of calcium accretion and depletion. The birds accumulate calcium between the start of lay and approximately 32 weeks, which presumably reflects the accumulation of medullary bone. By about 42 weeks the femur calcium content has decreased, presumably as a result of the birds attaining peak egg mass output. As the pressure of egg mass output reduces the bird is again able to replete skeletal calcium levels. Previous research on femur calcium content indicates that calcium content is strongly correlated with body weight.

Figure 19: Femur calcium content of 2 brown egg laying flocks (20 birds per sample point, standard error given) (■ - Sydney University trial, ● - ISA Brown flock)



Femur calcium contents are beginning to show a remarkable consistency across a large number of samples, but there may be important variation in the point of lay concentration, the peak calcium concentration and the extent of the skeletal mining in mid egg production. Some of the variation is explained by simple differences in pullet live weights, but it appears that skeletal calcium content can be similar in birds with different average live weights.

Given the likely significance of the sub-clinical cage layer fatigue described in Experiment 2, skeletal calcium content at point of lay and peak production will have important influences on productivity. Furthermore, it is clear from the results of Experiment 3 that standards of skeletal calcium content and body weight will be required to optimise productivity.

6. CONCLUDING COMMENTS

Experiment 1

1) Low appetite and the inappropriate synchronisation of appetite with early egg production is restraining the performance of brown egg layers housed in controlled environment conditions in Australia.

2) Using a phased increase in dietary calcium (mash diets) between 19-28 weeks of age had no effect on growth, feed intake and production from 19-40 weeks, and skeletal density at 40 weeks of age.

3) The stratification of the production performance within a flock indicates the importance of maintaining growth rates in birds between 20 to 26 weeks to achieving high levels of egg production.

4) In some flocks there is a proportion of the birds that have a reduced appetite response between 20-26 weeks. These birds are generally lighter as pullets, and experience a delayed peak production and a reduced persistency of production, and are responsible for constraining the overall performance of the flock.

5) An important question to be answered is whether the population of birds with a diminished growth response can be manipulated with management or is the solution genetic selection.

6) The reasons for the inappropriate appetite response in some flocks in early lay are not entirely clear at this stage, nor is the basis for the apparent genetic susceptibility within a flock. It seems likely, however, that this phenomena is primarily produced by environmental interactions and may be resolved by management.

Experiment 2

7) The performance of the Lohmann brown flock illustrated that weight loss in early production is not an inevitable consequence of high early egg production, provided that feed intake is appropriately synchronised with the dual demands for growth and egg production

Experiment 3

8) A period of feed restriction in pullets between 8 weeks of age and 16 weeks appears to produce a persistent stimulus to appetite once birds are allowed to consume feed *ad libitum*. The stimulus to appetite in early lay was associated with an enhanced production performance.

9) Careful exploitation of this response may be able to improve feed intakes of laying flocks in early egg production and produce profound effects on production capacity.

10) Successful management of these strategies will be dependent on the capacity to produce uniform pullets with the appropriate carcass composition at 8-12 weeks of age.

11) Feed restriction strategies will inevitably fail if the pullets are sub-optimal prior to restriction.

Laboratory Study

12) Studies of skeletal calcium reserves indicate that a diminished peak calcium reserve is likely to contribute to the expression of both osteoporosis and cage layer fatigue. A diminished pool of skeletal calcium is more likely in smaller pullets, but body weight alone will not explain all the variation observed.

13) The simple examination of the costochondral junction for nodulation and deformity has proven an effective method for studying osteoporosis and the number of birds with score (3-5) probably best defines the extent of the clinical problem.

14) Tissue reserves and appetite patterns in layers/pullets have profound effects on persistency of production. An ongoing analysis of these more complex parameters is required to ensure that the Australian Egg Industry can achieve the true production potential from the imported brown egg layers.

15) A comparative analysis with similar data collected from Europe and the United States will be required to consolidate information on the true genetic effect versus environmental interactions that may be peculiar to Australia.

7. IMPLICATIONS

The findings presented in this research program illustrate the potential production that can be achieved using the brown egg layer strains in Australia. Production levels of 320-330 eggs per hen housed appear possible, provided that a better balance of appetite, body weight and production can be achieved. This research highlights that the synchronisation of appetite with growth and production can be influenced by factor(s) other than temperature and dietary energy density. It is apparent from this research that attention to pullet growth rates, tissue reserves and appetite conditioning may provide the managerial approaches necessary to resolve these metabolic problems in highly productive birds. At this stage it is not clear whether these effects are additive or whether one factor, such as appetite conditioning, assumes a greater significance.

8. RECOMMENDATIONS

1. Continue to evaluate the production responses of commercial farms that have adopted modified pullet growth patterns with feed restriction.

2. Evaluate long term productivity of flocks subject to advanced early rearing and then feed restriction.

3. Establish another laboratory model using different pullets (strain?) that have been subject to the same rearing regime (advanced early rearing and feed restriction).

4. Continue to examine the variation in skeletal calcium contents in pullets and layers.

5. Establish additional models of cage layer fatigue and osteoporosis to define the significance of skeletal size.

6. Experimentation with even smaller pullets to improve efficiency and examine consequences on skeletal size.

9. INTELECTUAL PROPERTY

N/A

10. COMMUNICATION STRATEGY

1. Data was presented at the Victorian Egg Industry Seminar Day 1998.
2. An abstract was be prepared for publication in the PIX Conference in 1998.
3. A paper has been submitted to an international journal illustrating the correlation between growth patterns and production.
4. A paper will be prepared for the Australian Poultry and Feed Convention in October1999.

11. REFERENCES

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