RURAL INDUSTRIES RESEARCH
& DEVELOPMENT CORPORATION

Improvements in laying flock management to optimise performance in a changing industry

A report for the Rural Industries Research and Development Corporation

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Foreword

This project arose out of the need to address some of the management issues precipitated by a number of important developments within the Australian egg production industry. These changes have three main underlying causes. Firstly, de-regulation of the industry has led to a return to fluctuating prices due to inequalities in supply and demand, along with a sharp increase in interstate trading. Secondly, the importation of overseas parent stock, while undoubtedly leading to biologically more efficient egg production, has in many regions resulted in an over-supply of very large eggs to which the market in general has been unable to adjust. Thirdly, improved standards of welfare for poultry have been introduced, resulting in the need to modify some common husbandry practices. In addition there has been much to learn about the adaptability of these "new" strains of bird to the Australian environment – their resistance to disease, nutritional requirements and management, and the feasibility of retaining them for a second production cycle, which is an option often chosen by producers in difficult times. On the other hand many local strains of layer, with their relatively small egg size and poorer efficiency of feed conversion, present a very different set of problems which may necessitate opposing solutions.

This project addressed these problems mainly by studying management in the rearing period and some nutritional factors likely to influence egg weight in the first and second laying cycles. The two principal trials were conducted in a 1600-bird experimental layer-cage facility.

Since commencing this project the poultry industry has continued to undergo change, in particular a marked reduction in the use and availability of local strains, a sharp downturn in egg prices during the course of the trials (with some subsequent recovery) and a continuing trend toward monopolisation of the industry by larger producers and organisations, with an increasing trend toward direct contracts with large chain stores. These changes, together with some unforeseen developments in one of the experimental flocks, led to some minor changes in direction of the project during its progress. The revised project embraced most of the original objectives as well as the new aims.

Acknowledgments

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Contents

Abbreviations and Glossary

AE	Avian encephalomyelitis
CB	Hy-line (Australia) SIRO CB layer
Day-length	length of the light period provided in a 24-hour day
HB	Hy-line (Australia) Hyline Brown layer
HT	Hy-line (Australia) Tinted egg layer
IB	Baiada Isabrown layer
LB	Bartter Enterprises Lohmann Brown layer
LSD	Least significant difference
MD	Marek's disease
QPRDC	Queensland Poultry Research & Development Centre
ST	Ingham (Tegel) Super Tint layer

Executive Summary

A number of important developments have recently occurred in the Australian poultry industry. These include the introduction of overseas strains of layer, the move to de-regulation and unrestricted trading between states and the implementation of improved welfare standards for poultry. Compared with local strains of bird, the "imported" strains are generally more docile, lay much larger eggs, convert feed to eggs more efficiently and tend to be less resistant to disease organisms prevalent in the Australian environment. It is therefore probable that different management standards and strategies apply to these strains. Although dietary specifications recommended by the breeding companies are higher than for local strains, these standards have been questioned. The increasing use of imported strains has caused surpluses of very large eggs in many areas, resulting in a need for the development of feeding and management strategies to overcome this problem. With reduced prices for the largest grades of eggs, the viability of keeping flocks for a second production cycle has been put in doubt, though modified husbandry techniques for moulted birds might improve this prospect. The kinds of rearing techniques advocated in the past for local strains have also tended to result in an increase in average egg weight, and some of these techniques are now ethically unacceptable. Different rearing methods may therefore be appropriate not only for imported strains but for the industry in general.

To address the husbandry and nutritional questions arising from these developments, two long-term trials, each using two local and two introduced strains of layer, were conducted in a 1600-bird experimental layer-cage facility. The aims of the trials were to compare the profitability of early and late maturing strains of layer after advancing or delaying the onset of lay by means of feeding and husbandry techniques; to study effects of nutrient density, protein and linoleic acid level in the laying diet, with particular reference to egg size of imported strains during the first and second laying cycles; and to assess the response to moulting treatments and post-moult diets in birds of various strains exhibiting high or (as a result of a disease outbreak) very low rates of lay prior to moulting. Each trial comprised a rearing phase, an initial laying phase and a second laying phase following an induced moult, and the essentially factorial designs permitted an analysis of interactions between strains of bird and treatments applied at every stage of the trial. Where possible, results were evaluated in economic terms as well as statistically.

Trial 1 examined, in the rearing period, three lighting/feeding treatments designed to advance or delay maturity or to allow birds to mature at a normal rate; in the initial laying phase, low and high nutrient density diets; and in the second laying phase, the effects of induced moulting and nutrient density on recovery of birds exhibiting high or (as a result of an outbreak of Avian encephalomyelitis, AE) very low rates of lay prior to moulting. Trial 2 examined, in the rearing period, low and high nutrient density diets; in the initial laying phase, combinations of low and high dietary levels of protein and linoleic acid; and in the second laying phase, low and high nutrient density diets applied for a 23-day recovery period followed by combinations of low and high dietary levels of protein and linoleic acid.

It was found that average egg weight was markedly reduced and egg numbers were increased by the combined use of feeding and lighting techniques in the rearing period designed to hasten maturity. Conversely, egg weight tended to be increased at the expense of egg number when maturity was delayed. Feeding techniques alone during rearing, conducted within ethically acceptable limits, were not consistently efficient at controlling

egg weight. High dietary protein concentrations (approximately 180g/kg) during lay were found to increase egg weight of most strains, particularly in the first laying cycle, and sometimes increased financial margins in the first cycle but invariably resulted in substantially lower financial margins in the second laying cycle. High dietary linoleic acid concentrations (approximately 20g/kg) also tended to increase egg size, and the effect was greater in the second laying cycle than in the first. However, there appeared to be counter-productive changes in egg numbers and feed efficiency with the result that, for all strains of bird under most egg price structures, increasing the dietary linoleic acid reduced the average financial margin. The effects of protein and linoleic acid on egg weight were usually additive. Under most egg price structures the financial margin of the widely used imported strain, Isabrown, was higher with a high (approximately 180g/kg) protein diet than with a lower protein diet but the financial margin of other strains was not clearly affected by protein level. Following an induced moult, birds given a high protein, high linoleic acid diet for a 23-day period returned to lay more rapidly and with larger eggs than those given a lower specification diet. In one trial, in which a proportion of the flock suffered a production setback due to AE, the affected birds were not rehabilitated by either of two moulting treatments. Control birds that were unaffected by AE responded positively to these treatments. A diet of high nutrient density greatly improved the rate of lay, egg weight, egg shell quality and bodyweight of the AE-affected birds, as compared to a low-medium density diet.

These results have a number of implications for the poultry industry. Results of the rearing experiments indicate that lighting programs are an indispensable component of rearing management. Nutritional rearing methods alone, conducted in an ethically acceptable manner, are probably insufficient to ensure maximum returns over a full production cycle. A step-up lighting program together with a high specification grower diet increases total egg number and reduces mean egg weight in the first laying cycle. This may be economically advantageous for imported large-egg strains of layer.

Under most market conditions, the profitability of the Isabrown strain may be improved by feeding a diet with a high protein content in the first laying cycle, a medium/low protein content in the second cycle and low linoleic acid content throughout lay. Other strains may not need a high protein diet in the first cycle. The rapidly increasing use of imported strains is profoundly altering the relative proportions of different egg grades produced on farms. Producers will be able to apply the findings of this project according to the strain of bird used and with a view to meeting changes in consumer demand for different egg grades so as to maximise returns. However, management techniques such as those studied here provide only limited means of aligning the grade-mix produced on a farm with the saleable grade-mix.

Finally, it appears that birds which have suffered a severe set-back causing loss of bodyweight and production appear to require a high quality diet to assist recovery and are unlikely to be rejuvenated by induced moulting.

INTRODUCTION

General background

Two recent important developments in the Australian poultry industry are the introduction of overseas strains of layer and the move to de-regulation and unrestricted trading between states. These changes are having a considerable economic impact on the industry. The changed market conditions in particular have resulted in much lower returns, a climate of uncertainty throughout the industry and a still further contraction in the number of poultry farms. In addition, new standards of welfare for poultry have been introduced and these place restrictions on the husbandry techniques available to producers. As a result of these developments, producers have requested information on several related aspects of flock management, described below.

Most of the brown-egg strains recently introduced into Australia differ from typical local strains in a number of ways. They are remarkably docile birds which mature early, lay large eggs and convert feed to eggs extremely efficiently. Although their production may be sustained at close to peak levels for several months, later on the rate of lay tends to decline steeply and their response to induced moulting is not always satisfactory. Optimum rearing schedules for the imported strains are likely to be different from those suited to local strains, and different management may be required in the laying period if profitability is to be maximised. Previous studies involving multiple cycle regimens carried out at the QPRDC did indeed suggest that different strains respond divergently to different management strategies (Robinson *et al.* 1995; Robinson *et al.* 1996). Changing economic conditions, including lower egg prices and a price bias against large eggs throughout most of the year, may also affect the way that pullets should be reared to optimise economic performance. In some circumstances it may be more profitable to hasten maturity rather than to delay it by restricting feed intake (as commonly practised at present). While the most significant problem with imported strains to date has been their susceptibility to Marek's disease (MD), this specialised topic is beyond the scope of the present project.

Recommended nutrient densities for the introduced strains are also generally higher than for local strains. In a previous trial at QPRDC, however, one of these strains performed exceptionally well on a conventional diet. The need for high-specification diets for imported strains has been questioned (eg Nolan *et al.*, 1996), as has the suitability of Australian formulations based on meat and bone meal as the principal source of protein. Furthermore many producers keep mixed flocks and find it convenient to feed a single diet throughout the farm. They want to know whether a standard diet or one of higher specification should be used for flocks comprising both local and imported strains.

The retention of flocks for a second cycle of production has become an increasingly popular method of dealing with the “over-population” and egg price crises that mark the new era in the layer industry. However it has often been questioned whether imported strains can be gainfully moulted and put through a second cycle. Recently in some regions where market conditions were particularly unstable, some producers even adopted a policy of keeping birds out of production for long periods during adverse conditions, with the expectation of high returns when production resumed. These producers sought guidance concerning nutritional requirements of both local and imported strains during and immediately following the moult period, and a means of deciding when such a strategy is likely to be more economical than any alternative. As well, producers who were frequently operating at a loss wanted to know how their situation could be improved by changes in management procedures such as flock replacement times.

Another area of concern with imported strains of layer is their ability to tolerate the particular strains of pathogenic organisms found in Australia and the kinds of management required to reduce the risk of succumbing to disease and to assist recovery from disease. While it was not originally an objective of this project to venture into this area, the presence of disease turned out to be a serious problem in conducting the trials. When an opportunity arose to study the management of the birds following an outbreak of avian encephalomyelitis (AE), the project was revised accordingly.

Information addressing all these areas of concern, which are relatively new to the Australian poultry industry, would assist producers to adopt management strategies appropriate for their particular circumstances so as to maximise profits (or minimise losses).

Rearing pullets to modify subsequent production and egg weight

Although it has for long been known that lighting and nutrition during the growth period affect the age at maturity and subsequent performance of all strains of layers, the employment of husbandry practices such as reduced day-lengths and restricted feeding remains controversial. Delaying the time of reaching maturity by means of restricted feeding or step-down lighting in the rearing period has often been used to increase the average weight of all eggs laid up to a given age. A long-term response in egg production of White Leghorn x Australorp crossbred layers to a combination of restricted feeding and reduced lighting during rearing was demonstrated by Robinson (1978). With imported strains, however, the increase in average egg weight that usually results from such techniques may be detrimental in the present economic climate. Thus one of the main objectives of the current project was to find ways of encouraging imported large-egg strains to produce greater numbers of eggs at the expense of egg size. This appeared to imply the use of increasing day-lengths and liberal rather than restrictive feeding practices.

In Queensland, where seasonal differences in natural day-length are not great (at most three and a half hours between the winter and summer solstices), the simplest and most effective way of changing the day-length is to increase or reduce it in one step at between nine and twelve weeks of age. This has been shown to be the age at which pullets are most sensitive to changes in day-length in respect of the effect on age at maturity (Lewis *et al.*, 1992). Subjection to sudden massive reductions in day-length is a technique that has been used previously with considerable success (eg Robinson, 1978). Since most rearing sheds in Queensland cannot be kept dark, however, it is difficult to implement a satisfactory lighting program for pullets hatched between early August and the end of January.

Although it is widely recognised that, of all the nutritional techniques available for delaying maturity, restriction of feed intake is the most positive and effective, animal welfare considerations preclude the use of severe feed restriction (in Australia it is in contravention of animal welfare legislation to prevent access to feed for more than 24 hours at a time). It is therefore preferable to use a low density diet as the primary means of slowing pullet development, with short periods of non-access being applied only if the average liveweight of the pullets still exceeds the target weight. Conversely, it should be possible to hasten maturity by using a high protein, high density diet throughout the rearing period. In any case, if a step-up lighting program is employed to hasten maturity, the use of a high quality rearing diet appears to be desirable to ensure that the pullets commence lay with adequate stamina and body weight. This was essentially the rationale underlying the design of the trials conducted in this project.

Laying period nutrition and egg weight

Among the nutritional factors which affect egg weight are energy intake and the dietary concentrations of protein (or of various amino acids) and linoleic acid. Dietary energy concentration as such apparently has no effect on egg weight (Mannion 1990). Although energy intake can be reduced by restricting feed intake in lay, this is likely to reduce egg number as well as, or instead of, egg weight. A similar problem occurs with amino acids. Connor and Mannion (1986) showed that as the intake of lysine, methionine or isoleucine is reduced, egg number and weight decline and the effect on egg number is considerably greater than on egg weight. After analysing the results of a large number of experiments, Morris and Gous (1988) came to a similar conclusion, although at practical levels of inclusion the effects of protein on egg number and weight were approximately equal. Consequently, neither energy intake nor the dietary concentrations of amino acids show much potential for controlling egg weight, though further evidence is needed before entirely dismissing protein and certain specific amino acids. Recently it has been suggested that sulphur amino acids play a more important role than other amino acids in maintaining egg weight. The results of Calderon and Jensen (1990), for example, suggest that after the requirements of all the essential amino acids for maximum egg number have been satisfied, egg weight continues to respond to further increases in the daily intake of methionine + cystine.

A more effective way of altering egg weight nutritionally appears to be to modify the linoleic acid content of the diet. Mannion *et al.* (1992) reported that, in one of two strains of bird tested, a specific egg weight response to dietary linoleic acid occurred at intakes between 0.5 and 3.0 g/bird/day (corresponding to dietary linoleic acid levels of approximately 4 to 25 g/kg). Egg numbers were apparently unrelated to linoleic acid intake. Each 1g increase in daily intake resulted in an increase in average egg weight of 0.8-1.5g, the larger response occurring with older birds. The other strain of bird showed no significant response.

As imported strains of bird tend to lay eggs which are too large for current consumer requirements, they may benefit from nutritional regimens which aim to reduce average egg weight. Thus, while high dietary linoleic acid levels (20-30 g/kg) may be appropriate for all strains of bird at the commencement of lay (when egg size is small), low levels (<10 g/kg) would be preferable for imported strains after peak production, if these strains do exhibit an egg-size response to linoleic acid.

Nutritional management in the second laying cycle

Induced moulting or "resting" is a procedure that may be used to increase the profitability of an egg production enterprise particularly when there is a demand for large eggs or when pullet replacement costs are high. In the current Australian market, which is oversupplied with large eggs, an objective of second cycle management is to maximise egg numbers while minimising egg weight. Useful early indicators of satisfactory second-cycle production include adequate loss of body weight during the moult inducement period and a rapid recovery of weight following the moult (Baker *et al.,* 1981; Wolford 1984). A rapid return to a sustained peak of egg production is also desirable. There is evidence that low dietary protein levels in the period immediately following rest inducement may prevent adequate weight recovery and the attainment of maximum production (Koelkebeck *et al.,* 1993). Consequently, it is important to minimise egg size and maintain shell quality without compromising egg numbers. As has been mentioned, in the first laying cycle egg weight responds both to variation in the protein content of the diet and, in at least some strains of bird, to the linoleic acid content. It would be useful to know, especially for the imported layer strains, whether a high post-moult rate of lay can be achieved using diets with lower protein and/or linoleic acid concentrations than those recommended for the initial production cycle, so that egg weight is reduced.

Maintaining birds out of lay

One of the original aims of this project was to study the economics of layer flocks which are kept out of production for long periods. A few farmers have taken this option at times when egg prices have been too low to cover running costs or when unable to sell eggs through one of their usual outlets. Placing their trust in the inevitability of egg price cycles in a free market situation, these farmers assumed that sooner or later the market would recover and that flocks that had been rested for several months would resume full production when returned to a normal layer diet. As the project progressed, however, the need to study the nutritional requirements and economics of layers "on standby" became less compelling, as in practice very few producers were prepared to confront the uncertainties in this type of situation. Furthermore this aspect of the original proposal lost its appeal when the industry attained a generally healthier condition – only temporary, as it turned out. The decision was therefore made to alter this part of the research and concentrate instead on the successful moulting of imported strains and controlling egg size after the rest.

Management techniques to rejuvenate birds after disease

The nutrition and husbandry of laying strain birds in the growth and production phases are known to affect their reaction to the presence of disease organisms. Nir *et al.* (1996) argued that optimum immunocompetence may require a feeding regimen that does not maximise growth rate. Mortality of growing pullets challenged with *E. coli* was 20% with *ad libitum* feeding and only 7% with alternate day feeding (Katanbaf *et al.*, 1988). Zulkifli *et al.* (1993) showed that meat-type chicks restricted to 60% of *ad libitum* were more resistant to coccidiosis (*E. tenella*). This enhanced immune response has been attributed to the altered hormonal environment induced by feed restriction (Zulkifli *et al.*, 1995). Lower mortality during lay is a common response to feed restriction in the rearing period, especially in flocks infected with MD (Karunajeewa, 1976; Robinson and Sheridan, 1982). Choice feeding, using whole grains, and the use of high-fibre diets have been recommended as methods of increasing resistance to coccidiosis (Cumming, 1989). Induced moulting, followed by a high-grade nutritional regime, is sometimes recommended as a means of accelerating recovery from egg production drops, in particular egg-drop syndrome (e.g. Arzey, 1997). It is not known whether induced moulting and enhanced nutrition can be of assistance in all situations where a pathogen causes reduced egg output. As already mentioned, while it was not originally an objective of this project to study problems caused by disease, an egg production drop associated with AE occurred in the experimental flock which provided an opportunity to study the efficacy of moulting and enhanced nutrition in reducing production losses due to this disease. The project was therefore revised to investigate this question. (The circumstances leading to the revised proposal were reported in detail to the RIRDC on 17 September 1996, and are summarised in the Methodology). In addition, a common problem throughout these trials – as in the industry at this time – was the occurrence of MD in some strains of bird. Where there was evidence of an interaction with any of the experimental treatments, this is reported in the results.

Economic considerations – egg size

Supply and demand of different grades of eggs

An ongoing problem in the egg industry is the need to consistently meet consumer demand for various sizes of eggs throughout the year, and this has been exacerbated by the introduction of overseas strains of layers. Obviously, any discrepancy between the total output of a particular grade by farms and the consumer demand for that grade represents a substantial financial loss to the industry as a whole, and particularly to those producers who experience difficulties in achieving the required "grade mix". At the inception of this project, a payment system existed in Queensland which resulted in individual producers being severely penalised when the output from their farm did not correspond to the mixture of grades actually being sold by the marketing agency. This created immense difficulties especially for smaller producers wishing to use imported large-egg strains of layer. Although new contract arrangements with producers are now in place, the grading system originally in force for many years throughout Queensland, together with Queensland marketing data, will be used to illustrate the magnitude of the egg-size problem. The current Queensland system is essentially similar, and similar principles apply throughout Australia as there is a common need to maintain uniformity of supply of all egg grades.

At the start of this project, first quality eggs in Queensland were graded into five weight categories, approximately characterised as follows:

Economy (E)	-	38-45 grams
Medium (M)	-	45-52 grams
Large (L)	-	52-59 grams
Extra large (XL)	-	59-66 grams
Jumbo (J)	-	greater than 66 grams

There was also a desirable upper weight limit of 73 grams, and in this overview eggs exceeding this limit are termed over-size (OS). The average grade mix actually sold in 1994/95 is shown below, along with an estimate of the average annual demand. In reality demand depends on price and other factors such as consumer preferences (which appear to be changing), and a good estimate of demand involves an analysis of supply, consumption and prices. The estimate below was based on the numbers of each grade that were sold when sales were not limited by supply. This is in good agreement with an "off-the-cuff" marketing board prediction of demand in 1996. If this trend continues, there will be a diminishing demand for eggs in the middle of the weight range.

THE DEMAND FOR DIFFERENT EGG GRADES PREDICTED FROM 1994/95 SALES					
	Percent of total sales:				
	Economy + 2nds	Medium	Large	Extra large	Jumbo
Sales 1994/95	1.2	18.4	45.0	28.3	7.1
Demand 1996	1.1	20.2	41.3	28.0	9.4

Grading characteristics of imported strains and effect on prices

The average egg weight of mature imported brown-egg strains is approximately 4-5 g higher than that of most Australian strains. Furthermore, large eggs are produced earlier in life. This has a profound effect on the distribution of eggs between the grades. Graphs of the percentage of eggs falling into different grades are shown in Figures 1 and 2 for typical imported brown-egg strains and local tinted egg strains, respectively. The grade distributions were computed by a statistical technique similar to that used by McDonald (1986), and based on data from QPRDC trials. This procedure estimates the grade mix at a given age from knowledge of the age of commencing lay, the mature (maximum) egg weight and the standard deviations of egg weights. The proportion of second quality eggs was estimated using a model that relates the production of seconds to flock age and egg size. This model relates to the housing conditions and grading methods used at the QPRDC and may give higher or lower figures than those observed on other farms.

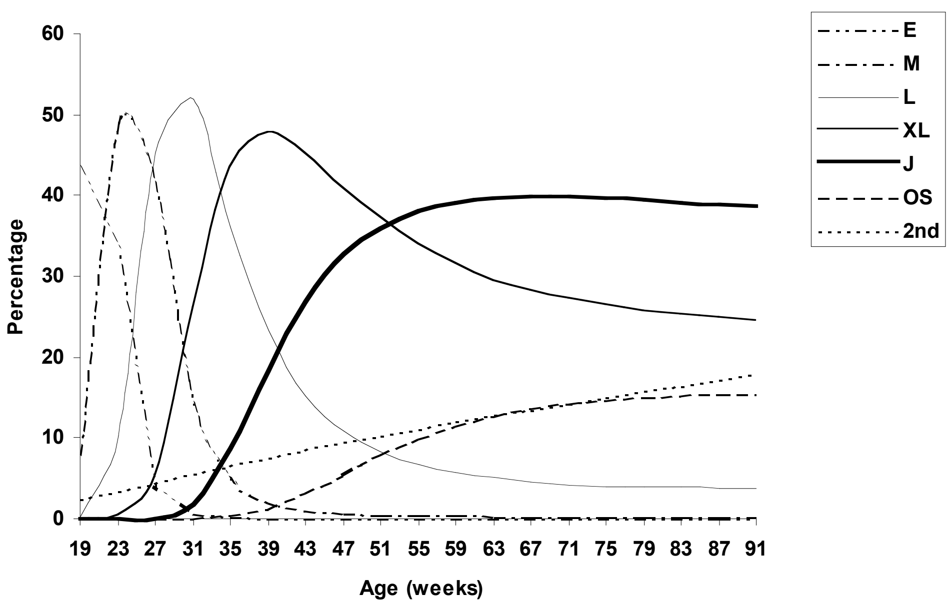
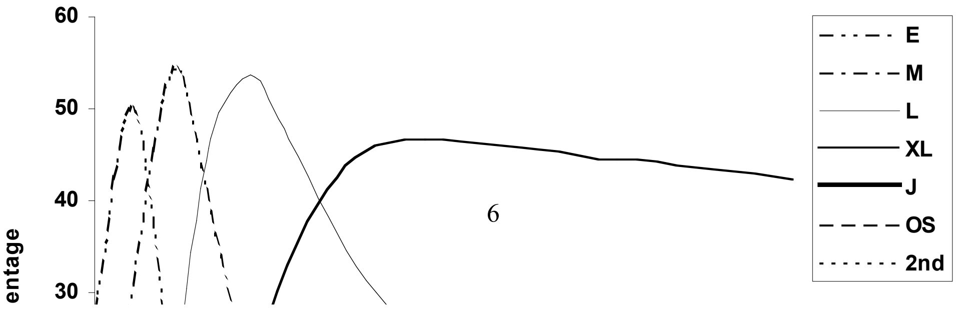


Figure 1. Typical grading of imported brown egg strains



The massive changes in the grade mix which occur during the life of the flock, whether of local or overseas descent, underline the impossibility of meeting the desirable grade mix on a single-flock farm (Table 1). At no time does the actual grade mix match the desirable mix, the imported strains producing on average too many XL and J and too few M and L eggs. The impact of the new strains on egg supply is reflected in the change in the relative net price paid to the producer for the different grades between 1994 and 1996 (Table 2). In 1996 the net value per kilogram was currently about 10% lower for XL and J than for M and L grades, while in the same month two years previously the price pattern favoured J followed by L. However the surplus of XL grade eggs was, and still is, a fairly persistent problem.

Table 1. The estimated demand for different grades (percent of total sales) compared with grade mix produced by imported and local strains

Grade	Demand	Imported strain at age:				Local strain Average
					Average	
		30 wks	55 wks	80 wks	18-70 wks	20-72 wks
E+2nd	1	6	11	16	11	13
M	20	18	0	0	9	15
L	41	51	7	4	20	31
XL	28	23	34	25	32	31
J	9	2	38	40	23	9
OS	-	0	10	15	5	1

Table 2. Queensland grade prices at 2nd March 1996

Grade	Gross	Charges	Net payment to producer		
	price, $	$/doz	$/doz	$/kg	$/kg (March 1994)
J	1.95/doz	0.3875	1.56	1.87	(1.60)
XL	1.80/doz	0.3875	1.41	1.88	(1.44)
L	1.80/doz	0.3875	1.41	2.12	(1.52)
M	1.65/doz	0.3875	1.26	2.17	(1.24)
E	0.65/doz	0.1775	0.47	0.94	(1.19)
2nd	1.30/kg	0.0925	0.83	1.17	(0.85)

Factors affecting on-farm grade distribution

While the grade mix produced by a farm depends mainly on the strains of birds kept and their ages, many other factors affect the grade mix, including nutrition, climate and season, rearing management, resting or moulting and disease. Unavoidable or unforseen changes in grade mix may occur as a result of disease outbreaks, quota cuts and management problems such as drinker-line and lighting failures. Hot weather, especially when hot enough to cause symptoms of heat stress, reduces egg size and increases the proportion of second quality eggs. This project is particularly concerned with factors that can be modified by the farmer during the rearing and laying phases. Rearing factors which delay maturity (such as declining daylength and restricted feeding) tend to increase the average weight of all eggs up to a given age (or a given total number of eggs), while factors which hasten maturity tend to have the opposite effect. Nutritional factors affecting egg size include feed restriction and dietary protein and fatty acid levels.

OBJECTIVES

The purpose of this project was to provide information on flock management problems which have arisen as a result of recent significant changes in the poultry industry, including the use of imported large-egg layers and changes to marketing and price structures. The project in its final form consisted of two long-term trials, the specific aims of which were as follows.

Trial 1

- To compare the profitability of early and late maturing strains of layer, including imported strains, after advancing or delaying the onset of lay by a combination of lighting and feeding techniques.
- To compare performance of these strains when given medium or high specification diets during lay.
- To assess the response to two moulting treatments and two post-moult diets in layers exhibiting high or very low rates of lay prior to moulting because of an outbreak of AE. This was primarily an evaluation of the ability of induced moulting to overcome the damaging effects of AE, but information relevant to healthy birds (controls) was also provided.

Trial 2

- To study the effectiveness of nutrient density of the starter and rearing diets on subsequent laying performance, particularly with a view to increasing egg numbers and reducing egg size in imported strains. This was an attempt to alter the rate of development of pullets without recourse to lighting and feed restriction programs.
- To compare the effectiveness of dietary lysine and linoleic acid levels for manipulating egg size.
- To improve the response to induced moulting by modifying post-moult nutrition, in particular to regulate egg size by means of lysine and linoleic acid during the second laying cycle.
- To observe the effects of pre-moult husbandry treatments on the response to moulting; and to observe other interactions, in particular differences between imported and local strains

METHODOLOGY

General Methods

This project consisted of two long-term trials designed to study aspects of nutrition and management relevant to recent developments in the poultry industry. Each trial used two local layer strains and two strains derived from imported breeding stock, and each comprised a rearing phase, an initial laying phase and a second laying phase following an induced moult. Pullets were purchased as day-old chicks from commercial hatcheries and were vaccinated according to recommended schedules for MD, infectious bronchitis, infectious laryngotracheitis, fowl pox and AE.

In the rearing phase chicks were brooded until four to five weeks of age in electrically heated multi-tier wire-floor brooders and were then transported to single-tier wire-floor grower cages. Brooder compartments each held approximately 25 chicks and rearing cages held approximately 18 pullets. Strains and rearing treatments (other than lighting treatments, where applicable) were randomised among compartments or cages. Lighting was a combination of natural daylight and fluorescent lighting. Water was available continuously, while feed was restricted for some birds during part of the growing period. At point of lay an equal number (384) of each strain of pullets were re-housed in two-bird wire layer cages, where they remained until termination of the trial. These cages were arranged in two tiers in an “A-frame” configuration, housed in a high-rise shed provided with adjustable shutters and ridge-vent, and thermostatically controlled fans and foggers. A day-length of 15½ to 16 hours was provided throughout the laying period by a combination of natural daylight and tungsten filament lights. An experimental unit in the layer shed consisted of a block of four adjacent two-bird cages supplied by a common feed trough. The birds in each cage had continuous access to two drinker nipples and feed was available *ad libitum*, even for birds undergoing an induced moult (when the feed consisted of uncrushed barley only).

Records consisted of group bodyweights and feed intake at appropriate intervals during the rearing phase, and daily egg production (five days/week), fortnightly egg weight and egg grading, daily number of visible egg defects at egg collection time, monthly feed intake, and bodyweights, egg specific gravities and (Trial 1 only) egg Haugh units at occasional intervals throughout the laying period. Abdominal fat pads were removed and weighed at termination of Trial 2. In the laying phases all records were on a group basis except for bodyweight, specific gravity and Haugh unit score, which were measured on individual birds or eggs. Data were statistically analysed predominantly by analysis of variance using Statistix or Genstat packages or programs written in Unix “awk” language specifically for the project. An elementary economic assessment of the main laying performance results was carried out as described at the beginning of the Economics section.

Trial 1

The original project plan comprised a rearing phase, an initial laying phase terminating at 65 weeks of age and a secondary phase terminating at 95 weeks. The secondary phase was to have studied the feasibility and management of “maintenance” treatments (very long rests) followed by a second production cycle. For reasons described below, the initial laying phase was terminated at 53 weeks of age and the proposed secondary phase was replaced by a different study. The final design was a partial factorial comprising four strains of bird, three rearing treatments, two nutrient densities in the initial laying phase, three moulting treatments (including an unmoulted control) applied to two categories of birds based on their pre-moult production status, and two post-moult diets. The four strains of bird were: Baiada Isabrown (IB), Bartter Enterprises Lohmann Brown (LB), Ingham (Tegel) Super-tint (ST) and Hy-line (Australia) SIRO CB (CB). The husbandry treatments are described in detail below.

Rearing phase

In this trial the aim of the rearing treatments was to induce pullets of two local and two imported strains to mature at three different times:

Normal:	Maturity at normal average age and normal average body weight. ("Normal" means under average husbandry conditions, not necessarily in accordance with breeding company recommendations).
Advanced:	Maturity approximately two weeks in advance of normal, at a higher than normal weight-for-age.
Delayed:	Maturity approximately two weeks later than normal, at a lower than normal weight-for-age.

Four hundred and eighty pullets of each of the two imported strains (IB and LB) and two local strains (ST and CB) were obtained. The local strains were selected mainly because of their popularity, tendency to mature late and moderate egg size, in contrast to the early age of maturity and large egg size of the imported strains. The objectives of the rearing treatments were achieved by using a combination of feeding and lighting techniques, applied throughout the rearing period (Table 3).

Table 3. Rearing treatments

Treatment	Starter and grower diets	Feeding	Lighting
Normal	Low density	Mainly *ad libitum* with mild restriction when required	15 h from 3 days to 19 weeks of age
Advanced	High density	*Ad libitum*	Natural daylight from 3 days to 10 wks, 15 h from 10 to 17 wks
Delayed	Low density	Restricted from 9 wks until 5% production	20 h from 3 days to 10 wks, 15 h from 10 to 21 weeks of age

Application of the three lighting treatments necessitated using three different rooms until ten weeks of age, when the advanced and retarded groups received a sudden increase or a sudden reduction in daylength. The reason for changing the daylength in one step at ten weeks of age, rather than using a gradual change, was to produce the maximum effect on age at maturity, as it is known that pullets are most sensitive to daylength changes at 10-12 weeks of age (Lewis *et al.*, 1992).

Table 4. Composition and nutrient analysis of the starter and grower diets used in Trial 1

Composition (kg/tonne)	High starter	Low starter	High grower	Low grower
Wheat (12%)	250	350	250	383
Sorghum (9.5%)	396	300	435	300
Lucerne HQ	-	56	-	75
Millrun	-	50	76	68
Soybean (45%)	190	82	57	20
Sunflower (32%)	64	76	98	97
Meat & bone (50%)	75	72	70	34
Soybean oil	5.7	1.1	0.3	-
Limestone	4.7	2.5	3.1	5.1
Dicalcium phosphate	4.3	1.1	5.4	12
Salt	1.9	1.6	1.7	2.1
DL Methionine	2.2	1.7	1.2	0.9
Lysine mono HCl	1.9	2.4	0.5	1.0
Vit premx	1.5	1.5	1.0	1.0
Min premx	1.5	1.5	1.0	1.0
Choline Cl	1.2	1.0	0.47	0.42
Total (kg)	999.9	1000.4	1000.67	1000.52

Nutrient specifications	High starter	Low starter	High grower	Low grower
ME (kcal/kg)	2950	2750	2850	2650
ME (MJ/kg)	12.3	11.5	11.9	11.1
Protein %	20.5	18	17	15
ME(kcal)/protein	144	153	168	177
Calcium %	1.2	1.05	1.15	1.0
Available Phos %	0.6	0.53	0.60	0.53
Lysine %	1.1	0.95	0.71	0.63
Methionine %	0.43	0.38	0.32	0.28
Met+Cys %	0.78	0.68	0.61	0.54
Tryptophan %	0.22	0.19	0.16	0.14
Threonine %	0.71	0.62	0.55	0.48
Isoleucine %	0.75	0.66	0.62	0.55
Sodium %	0.16	0.14	0.16	0.14
Linoleic acid %	1.2	1.05	1.1	0.95

The composition of the rearing diets is shown in Table 4. Feed restriction (where used) was applied by limiting time of access to the feeders. Commencing at nine weeks of age, time of access for the delayed birds was limited initially to six hours daily, reducing to approximately three hours daily by fourteen weeks of age. Shorter feeding periods were sometimes given in order to control growth rate satisfactorily. After twelve weeks of age, birds on the “normal” treatment also had limited access time to feed when necessary, varying from five to seven hours daily.

Pullets were transferred to laying quarters between 16 and 21 weeks of age, depending on readiness to lay. Feed restriction of local strains in the delayed maturity treatment, which commenced lay very late, was continued in the laying shed until approximately 22 weeks of age (5% rate of lay).

Laying phases

Within a given strain and rearing treatment, each replicate-group in the laying shed comprised four pairs of birds, each pair being drawn at random from a different rearing cage (so that each replicate comprised birds from four different regions of the rearing shed). There were eight such replicates of every strain by rearing combination except the "normal" rearing treatment, which was represented by 32 replicates for each strain. (Due to high rearing mortality, however, the CB and LB strains had slightly fewer “normal” replicates). In the initial laying phase, all birds from the advanced and delayed rearing treatments received a low-medium density diet, while the “normal” rearing treatment birds were given either this diet or a high density diet. Typical ingredient compositions of the layer diets are shown in Table 5. Similar ingredients were used throughout the trial but the proportions of ingredients in the diets varied according to their analysis. The low density diet contained 11.2 MJ/kg ME, 155g/kg protein, 7.2g/kg lysine and 10g/kg linoleic acid and had an ingredient cost of approximately $244/tonne. The high density diet contained 12.1 MJ/kg ME, 186g/kg protein, 8.4g/kg lysine and 18g/kg linoleic acid and had an ingredient cost of approximately $269/tonne.

Table 5. Typical composition of diets used in the first laying phase of Trial 1 (kg/tonne)

	High density	Low density
Sorghum (11%)	500	506
Wheat (15%)	150	150
Millrun	-	150
Soyabean (48%)	164	55
Meat & bone (50-52%)	55	40
Ground limestone	50	42
Limestone grit	50	50
Blended oil	24	24
Salt	1.600	1.500
DL Methionine	1.800	1.400
Lysine HCl	0.310	2.100
Choline Cl	0.480	0.450
Vitamin premix	1.100	1.000
Mineral premix	1.100	1.000
Yolk pigment	0.056	0.050
	999.5	1000.5

The original project proposal was revised owing to an outbreak of AE which resulted in early termination of the initial laying phase. The circumstances of this problem were fully described in a report, including pathological evidence, accompanying the revised project submission. In brief, a marked drop in production accompanied by broken eggs was first detected in two adjacent groups of birds at approximately 53 weeks of age. These symptoms were then noticed in increasing numbers of birds throughout adjacent areas of the shed. Recovery of initially affected birds was slow, while spread of the disease through the flock also continued slowly. At 65 weeks of age, which was the time scheduled to begin the second stage of the project, a decision was made to terminate the trial. At this stage the average rate of lay of the entire flock was approximately 50%, with a range between experimental groups of 0-89%. As there was a fairly sharp distinction between affected and unaffected groups of birds, it was possible to divide the bulk of the flock into two equal parts, having average laying rates of approximately 27% and 74% and equally representing all strains and prior treatments. This unique situation provided a valuable opportunity to study management strategies aimed to assist recovery from AE. As resting has been used effectively under field conditions as a means of recovery from low production (especially when caused by the adenovirus responsible for egg-drop syndrome) it was considered appropriate to use resting methods in the present situation. Also a prominent feature of the disease as experienced in this outbreak was the very high proportion of broken eggs, and it was considered that resting might rectify this problem. As many of the affected birds were in poor condition, it also seemed appropriate to find out whether the use of a high nutrient density diet following the rest inducement period would improve post-rest performance. As it was necessary to promote recovery of the birds soon after obtaining a positive diagnosis, and when it became apparent that rapid recovery would not occur unaided, the resting treatments were started at approximately 66 weeks of age. For reporting purposes, the first laying phase was considered to be terminated at 53 weeks of age, before the onset of the production drop.

Thus the second laying phase of this trial began with two sets of birds, each comprising 72 groups with each group containing 6-8 birds in two-bird cages. The two sets had mean initial production levels of 27% and 74% and mean body weights of 1.773 kg and 1.994 kg respectively, and the mean egg weight of the second set was approximately 1.4g higher than that of the first during the month prior to commencing the treatments described below. At 66 weeks of age the two sets were divided into three sub-sets: unmoulted, moulted by feeding barley for nine days (short moult) and moulted by feeding barley for 18 days (long moult). The experiment also included two post-moult diets (low and high nutrient density), which were fed from the end of the moult inducement period until the end of the four-month trial. However, the design precluded an analysis of certain treatment interactions.

Table 6. Typical composition of diets used in the second laying phase of Trial 1 (kg/tonne)

	High density	Low density
Sorghum (9.5%)	329	518
Wheat (14.4%)	332	150
Millrun	-	19.5
Soyabean meal(48%)	159	68
Sunflower meal (32%)	-	108
Meat & bone (50-52%)	63.5	25
Ground limestone	37.4	41.7
Limestone grit	50	50
Dicalcium phosphate		10.5
Blended oil	23.5	0.7
Salt	1.670	2.200
DL Methionine	1.130	1.390
Lysine HCl	0.230	2.550
Choline Cl	0.450	0.400
Vitamin premix	1.100	1.000
Mineral premix	1.100	1.000
Yolk pigment	0.055	0.050
	1000.1	1000.0

Trial 2

This experiment was a randomised block factorial with the following factors:

Strains:
Four strains of bird: Baiada Isabrown (IB), Hy-line (Australia) Hyline Brown (HB), Hy-line (Australia) SIRO CB (CB), and Hy-line (Australia) Tinted egg layer (HT)

Rearing phase treatments:
Two nutritional regimens in the growing period (4-17 weeks of age): "low" and "high" specification diets (15.0% protein and 10.95 MJ/kg ME, and 18.6% protein and 12.3 MJ/kg ME); the "low" diet was fed restrictively from 12 to 17 weeks of age.

Initial laying phase (18-64 weeks of age):

Four laying diets:
- Low protein (165g/kg), low linoleic acid (8.5g/kg)
- Low protein (165g/kg), high linoleic acid (24g/kg)
- High protein (183g/kg), low linoleic acid (8.5g/kg)
- High protein (183g/kg), high linoleic acid (24g/kg)

(See remarks in Discussion of Results about the nominal use of the words "protein" and "linoleic acid")

Second laying phase (post-moult):

One unmoulted control and five post-moult nutritional regimens:

Treatment ID	Moult	Recovery diet ID	Post-recovery diet ID
1	no	B	B
2	yes	A	B
3	yes	D	B
4	yes	A	C
5	yes	A	D
6	yes	D	D

These treatments are described in more detail below.

The aim in the rearing stage was to try to alter mature body weight and time of reaching maturity without using lighting programs and complicated feed restriction regimens as had been used in the first trial. The composition of the rearing diets is shown in Table 7. Since these diets produced only small differences in body weight by 12 weeks of age, birds on the low density diet were restrictively fed from 12 to 17 weeks using an alternate day feeding program. A 15-hour constant day-length was used. The average body weight difference between treatments at 17 weeks of age was 8.4% for the local strains and 15.7% for the imported strains (Table 10).

Table 7. Composition of the rearing diets used in Trial 2 (kg/tonne)

	High	Low
Wheat (12%)	100	101
Sorghum (8%)	582	475
Lucerne HQ	25	49
Millrun	-	157
Soybean (Amer 48%)	78	14
Cottonseed	50	-
Sunflower (32%)	59	150
Meat & bone (50%)	97	25
Soybean oil	3.1	-
Limestone	-	10
Dicalcium phosphate	-	13.2
Salt	1.4	1.4
DL Methionine	1.1	0.6
Lysine	0.59	1.64
Vit premx	1.2	0.9
Min premx	1.2	0.9
Choline Cl	0.50	0.40
Total	1000.09	1000.04

At 16-17 weeks of age the pullets were re-housed in the laying accommodation (see General Methods). Twelve 8-bird replicates of each strain were allotted to each of the four "first-cycle" nutritional treatments. The composition of these layer diets is shown in Table 8.

Table 8. Typical composition of diets used in the first laying phase of Trial 2 (kg/tonne)

Protein: Linoleic acid:	Low Low	Low High	High Low	High High
Sorghum (8%)	210	252	522	252
Wheat (12%)	516	366	120	322
Millrun	-	54	-	54
Soyabean meal (49%)	112	112	160	147
Cottonseed meal (exp)	-	50	36.5	50
Meat & bone (50%)	67	37	66	49
Ground limestone	39	49	39	47
Limestone grit	50	50	50	50
Sunflower oil	-	23.6	-	24
Salt	2.250	2.400	1.900	2.200
DL Methionine	1.500	1.400	2.080	1.800
Choline Cl	0.400	0.400	0.400	0.400
Vitamin premix	1.000	1.000	1.000	1.000
Mineral premix	1.000	1.000	1.000	1.000
Yolk pigment	0.050	0.050	0.050	0.050
Total	1000.2	999.8	999.9	999.7

Owing to very high mortality in the HB strain in the early part of the laying period due to MD, replicate-groups of this strain were combined at the end of the eighth and 28th weeks of the initial laying phase to form reduced numbers of replicates on each nutritional treatment. Statistics on performance parameters were done with and without strain HB, a "replicate" in the former case being either a true replicate or a combination of two of the original replicates.

At 64 weeks of age the experimental groups were re-allocated to second-cycle treatments. Moulting (treatments 2-6 above) was induced by feeding the birds only whole barley for 18 days. Moulted birds were then placed on one of two recovery diets for a 23-day period, following which they received one of three second-cycle diets which were fed for the remainder of the laying period (post-recovery period), terminating at 100 weeks of age. These diets (for composition see Table 9) differed in protein content and linoleic acid content as shown below. Due to the diminished numbers of strain HB, there were insufficient experimental units of this strain to apply all the second-cycle treatments. Therefore only treatments 1, 2, 4 and 5 were tested in strain HB.

Post-moult diets:

Diet ID	**Met. energy (MJ/kg)**	**Protein g/kg**	**Linoleic acid g/kg**
A	11.5	145	8.8
B	11.7	156	8.2
C	11.8	156	20
D	11.8	178	20

Table 9. Typical composition of diets used in the second laying phase of Trial 2 (kg/tonne)

	A	B	C	D
Sorghum (8.6%)	518.1	577.3	566.2	148.8
Wheat (10.4%)	202	140	124	500
Soyabean meal (48%)	82	132	-	190
Soyabean meal (44%)	-	-	142	-
Sunflower meal (32%)	44	-	-	-
Meat & bone (50%)	50	52	52	36
Ground limestone	40.6	38.8	38.8	44
Limestone grit	50	50	50	50
Sunflower oil	-	-	18	20
Dicalcium phosphate	-	-	-	3.800
Salt	2.000	2.000	2.000	2.500
Electrolytes ($NaHCO_3$, $KHCO_3$)	6.500	3.500	2.500	-
DL Methionine	1.210	1.360	1.340	1.800
Lysine mono HCl	1.140	0.690	0.720	0.160
Choline Cl	0.400	0.400	0.400	0.400
Vitamin premix	1.000	1.000	1.000	1.000
Mineral premix	1.000	1.000	1.000	1.000
Yolk pigment	0.050	0.050	0.050	0.050
Total	1000.0	1000.0	1000.0	1000.0

At termination of the trial, 52 birds representing pre- and post-moult treatments were killed and the abdominal fat pad was removed and weighed.

DETAILED RESULTS

Trial 1

Rearing period

The main results up to point of lay are shown in Table 10 and some intermediate bodyweight and feed intake results in the rearing period appear in Tables 11 and 12. The rearing treatments achieved a high degree of separation of times of commencing lay. Ages of reaching 5% rate of lay and bodyweights at 17 weeks of age differed markedly between rearing treatments (P<0.001). However the difference between advanced and normal pullets was usually greater than between normal and delayed pullets. A wider range of weights was achieved at 17 weeks with strain ST than with other strains (Table 11). Normally reared pullets had the highest bodyweights at point of lay. For strains IB and LB, the advanced birds commenced lay at considerably lower bodyweights than the normal and delayed birds. Weights at five weeks of age were higher for the delayed birds than for the normal birds: this is because at this stage the delayed birds were receiving the same diet but a longer light period than the normal birds (see Methods). Mean feed intake of the delayed treatment was higher (P<0.001) than that of the other treatments from 0-5 weeks and lower (P<0.001) in the remainder of the rearing period.

The rather high mortality rate in the rearing period (Table 13) was attributable mainly to MD. The percentage mortality of all strains except ST (which was unaffected by MD) was higher in the delayed treatment than in the normal and advanced treatments (significant for strains IB and CB, P<0.05).

Table 10. Age and bodyweight at maturity

Strain	Rearing treatment	Age (days) at 5% production	Mean bodyweight (kg): 17 weeks	5% production
IB	Advanced	104	1.675	1.467
	Normal	133	1.587	1.748
	Delayed	145	1.428	1.647
LB	Advanced	106	1.742	1.578
	Normal	133	1.601	1.864
	Delayed	143	1.405	1.708
ST	Advanced	122	1.656	1.674
	Normal	139	1.450	1.735
	Delayed	157	1.329	1.678
CB	Advanced	128	1.678	1.773
	Normal	146	1.553	1.875
	Delayed	158	1.420	1.802
LSD (P<0.05)		10.2	0.084	0.155

Table 11. Bodyweights in the rearing phase

Strain	Rearing treatment	Bodyweight at week: 5	12	17	Proportional wt at wk 17 (normal = 100)
IB	Advanced	392.3	1272.2	1675.1	105.5
IB	Normal	368.0	1252.9	1587.5	100
IB	Delayed	376.4	1148.6	1428.0	90.0
LB	Advanced	389.3	1285.6	1741.6	108.8
LB	Normal	347.8	1250.0	1601.4	100
LB	Delayed	401.5	1136.0	1404.7	87.7
ST	Advanced	370.8	1152.8	1656.3	114.3
ST	Normal	357.1	1120.3	1449.5	100
ST	Delayed	385.6	1061.8	1329.4	91.7
CB	Advanced	393.1	1239.1	1678.3	108.0
CB	Normal	355.3	1200.1	1553.4	100
CB	Delayed	366.5	1128.0	1420.3	91.4
LSD (P<0.05)		25.9	70.4	84.4	-

Table 12. Feed intake in the rearing phase

Strain	Rearing treatment	Feed intake for period (weeks): 0-5	5-12	12-17	0-17
IB	Advanced	786.1	3185	2770	6741
IB	Normal	792.1	3314	2720	6816
IB	Delayed	833.4	2847	2356	6036
LB	Advanced	806.4	3046	3193	7045
LB	Normal	794.1	3153	2983	6930
LB	Delayed	872.0	2753	2234	5839
ST	Advanced	788.3	2940	3179	6907
ST	Normal	810.8	3009	2688	6508
ST	Delayed	861.1	2730	2167	5758
CB	Advanced	832.0	3199	2766	6797
CB	Normal	819.9	3248	2626	6694
CB	Delayed	938.2	2944	2206	6088
LSD (P<0.05)		53.3	239	262	490

Table 13. Mortality (%) 4-17 weeks of age

Rearing treatment	Strain: IB	LB	ST	CB	Mean
Advanced	5.25	4.87	3.90	9.50	5.88
Normal	4.83	5.03	5.03	13.58	7.12
Delayed	10.98	8.89	3.22	19.90	10.75
Mean	7.02	6.26	4.05	14.33	7.92
LSD (P<0.05)	4.46				2.23

Initial laying phase

Overall performance results for the initial laying phase (17-53 weeks of age) are presented in Table 14. Hen-day egg number of imported strains was higher on the advanced rearing treatment than on the normal ($P<0.05$) or delayed ($P<0.001$) treatment. Egg number of local strains was higher ($P<0.05$) on the advanced treatment than on the delayed treatment. Average egg weight was lower on the advanced treatment than on other treatments (imported strains $P<0.05$, local strains $P<0.001$). Egg weight measured at any given age was also lower on the advanced treatment. Except in strain IB, which had a lower ($P<0.05$) feed intake on the delayed than on the advanced treatment, feed intake during lay was unrelated to rearing treatment. In the last four months of lay egg production and feed conversion tended to be poorer for the advanced birds than the normal and delayed birds. Feeding the higher density diet during lay reduced feed intake ($P<0.001$) in all strains, improved feed efficiency ($P<0.05$) in two strains and tended to increase egg weight in the two imported strains and to reduce it in the local strains. Egg number was apparently increased on the high diet only in strain IB (approaching significance at $P=0.05$). The percentage of downgraded eggs (predominantly cracks), egg specific gravity and Haugh unit score were unaffected by treatment. Average specific gravities for strains were IB 1.0869, LB 1.0848, ST 1.0813, CB 1.0818. The treatments had no consistent effect on mortality across the strains; however, mortality of the CB strain was higher (P<0.05) in the advanced treatment than in the normal or delayed treatment. The results indicate that the mortality rate of the strain which was most severely infected with MD (CB) was highest in the group which had been boosted in rearing and lowest in the group that had been restricted. While the ST strain also followed this trend, the laying period mortality of the two imported strains was unaffected by rearing treatment.

Table 14. Effects of strain, rearing treatment and layer diet on laying performance from 17 to 53 weeks of age

Strain/husbandry treatment*	Eggs/ bird (hen-d)	Down-grades (%)	Mean egg wt(g)	Egg mass (g/d)	Feed intake (g/d)	Feed/ egg (g/g)	Mortal-ity (%)
IB-A	227.38	5.19	57.90	52.23	119.71	2.294	9.38
IB-N	206.61	5.02	61.31	50.18	118.76	2.372	15.63
IB-D	199.98	4.49	61.29	48.64	115.41	2.376	12.50
IB-NH	217.73	5.19	61.93	53.50	113.75	2.127	10.94
LB-A	221.54	4.92	58.65	51.62	118.82	2.314	14.06
LB-N	201.73	3.91	61.77	49.36	117.51	2.386	13.00
LB-D	201.25	5.91	63.03	50.31	119.86	2.385	14.29
LB-NH	202.03	4.57	62.39	50.02	112.20	2.251	12.50
ST-A	207.59	5.15	54.64	45.02	114.00	2.533	9.38
ST-N	198.95	5.08	58.06	45.79	117.10	2.560	8.93
ST-D	192.83	4.99	58.36	44.66	115.22	2.582	3.13
ST-NH	200.86	4.17	57.57	45.86	109.03	2.381	12.50
CB-A	205.11	4.13	54.48	44.35	120.06	2.713	25.00
CB-N	195.75	6.42	59.33	45.92	122.54	2.676	11.61
CB-D	185.62	3.83	58.84	43.33	121.22	2.803	8.93
CB-NH	197.23	5.49	56.80	44.44	117.92	2.655	12.50
LSD (P<0.05)	11.35	2.36	1.97	14.74	2.33	0.211	10.69
Mean-A	215.40	4.85	56.42	48.31	118.15	2.463	14.45
Mean-N	200.76	5.11	60.12	47.81	118.98	2.498	12.29
Mean-D	194.92	4.81	60.38	46.74	117.93	2.536	9.71
Mean-NH	204.46	4.86	59.67	48.46	113.23	2.353	12.11
LSD husbandry means (P<0.05)	5.68	1.18	0.98	0.87	1.16	0.106	5.34

* A advanced, N normal, D delayed (all followed by low density layer diet), NH normal rearing followed by high density layer diet. For comparison of layer diets, treatment NH can only be compared with treatment N. Rearing period results for NH are the same as for N.

Second laying phase

Results for the post-moult laying period are presented for the two categories of birds (low and high production rates prior to moulting), the type of moult (short, long and none) and the post-moult diets (low and high nutrient density). As main effects are of little interest, only first order interactions are presented, and as all four strains of bird responded similarly to the husbandry treatments, individual strain results are not shown.

Egg production data (Table 15) show that the birds which were laying at a low rate prior to moulting (i.e. birds assumed to be affected by AE) continued to perform badly, regardless of moulting treatment. The short moult had no effect on subsequent rate of lay of these birds. Moulting was more effective for the previous high producers than for the low producers. The high density diet fed after the moult inducement period markedly improved the production of the previous poor producers, however it did not raise their performance to the level of the previous high producers. The rate of lay of the latter birds was not significantly affected by diet. In general the administration of a long moult followed by the use of a high density diet resulted in optimum levels of production.

Table 15. Rate of lay (%)

Pre-moult	Moult type:			
category	None	Short	Long	Mean
Low producers	39.1	39.2	43.2	40.6
High producers	61.7	69.6	75.3	68.9
LSD (P<0.05)	8.1			4.7

Pre-moult	Post-moult diet:	
category	Low density	High density
Low producers	30.6	50.4
High producers	67.6	70.2
LSD (P<0.05)	6.6	

Moult	Post-moult diet:	
type	Low density	High density
None	45.5	55.3
Short	50.4	59.7
Long	52.7	65.9
LSD (P<0.05)	6.6	

Moulting tended to increase the mean egg weight only of the birds that were laying well prior to moulting (Table 16); the disease-affected birds showed no egg weight response to moulting. Compared with the low density diet, the high density diet increased mean egg weight by 4.2g in the low producers and by 2.3g in the high producers.

Table 16. Mean egg weight (g)

Pre-moult	Moult type:			
category	None	Short	Long	Mean
Low producers	64.4	64.7	63.7	64.3
High producers	65.1	66.5	66.2	65.9
LSD (P<0.05)	1.95			1.13

Egg candling results indicated a very high proportion of defective eggs throughout the flock (Table 17). The majority of defects were cracks due to thin shells, with previous low producers having twice as many cracks as the high producers. Moulting reduced the incidence of defects in the previous high producers but had little effect on the shell quality of the disease-affected birds. In contrast, the high density diet reduced the proportion of shell defects in the latter group but had no effect on shell quality of the high producers. The ameliorative effect of the high density diet on shell quality was greatest in the long-moulted birds and least in the unmoulted birds. Specific gravities of eggs tended to reflect the percentage of shell defects, with significant ($P<0.05$) differences between low and high producers, between moulted and unmoulted high producers, and between low and high density diets for the low producers.

Table 17. Defective eggs (%) detected by candling

Pre-moult	Moult type:			
category	None	Short	Long	Mean
Low producers	55.6	54.7	47.2	52.5
High producers	32.7	22.8	19.5	25.0
LSD ($P<0.05$)	11.8			6.2

Pre-moult	Post-moult diet:	
category	Low density	High density
Low producers	62.6	42.6
High producers	24.4	25.7
LSD ($P<0.05$)	8.7	

Moult	Post-moult diet:	
type	Low density	High density
None	45.9	42.5
Short	42.4	33.8
Long	40.6	26.1
LSD ($P<0.05$)	10.6	

Feed intake of the low-producing category of birds was substantially less than that of the high-producing category (Table 18). However, while the high producers on the low density diet ate more feed than those on the high density diet, the low producers had the opposite response to dietary density. The moulting treatments did not affect this response: regardless of other treatments, feed intake increased with increasing length of moult (no moult 104.9, short moult 106.3, long moult 110.7g/day; LSD ($P<0.05$) = 5.3).

Table 18. Feed intake (g/day)

Pre-moult	Post-moult diet:		
category	Low density	High density	Mean
Low producers	95.8	103.4	99.7
High producers	116.8	112.6	114.7
LSD ($P<0.05$)	6.1		4.3

Trial 2

Rearing period

Strain and feeding treatment effects on growth and feed intake in the rearing period are shown in Table 19. The average body weight difference between feeding treatments at 112 d (16 weeks) of age was 15.7% for the imported strains and 8.4% for the local strains, while the difference in age at maturity (5% rate of lay) was 8-10 days for the imported strains and 10-11 days for the local strains. Feed intake from 32 to 67 days was lower (P<0.05) on the low density diet than on the high density diet. Despite restrictive feeding of the low density diet later on, total feed intake (32-112 days) differed little between the two feeding treatments, except for the IB strain whose feed intake was lower on the low diet than on the high diet.

Table 19. Effects of strain and rearing diet on bodyweights and feed intake in the rearing phase and on age at maturity

Strain	Rearing treat.	Bodyweight (g): 67d	Bodyweight (g): 112d	Proportional bwt at 112d	Feed intake (g) 32-67d	Feed intake (g) 67-112d	Age at 5% prodn (days)
IB	High	609.5	1465	100	1108	3613	132
IB	Low	554.7	1260	86.0	914	3528	142
HB	High	562.1	1443	100	981	3368	129
HB	Low	517.9	1191	82.5	901	3416	137
HT	High	474.7	1188	100	828	3037	139
HT	Low	459.0	1118	94.1	725	3278	150
CB	High	548.9	1334	100	1005	3439	145
CB	Low	505.8	1192	89.4	832	3466	155
LSD (P<0.05)		43.8	106	-	131	248	11
Mean	High	548.8	1358	100	981	3364	136
Mean	Low	509.4	1190	87.6	843	3422	146
LSD (P<0.05) rearing treat. means		21.9	5.3	-	66	124	6

Rearing period mortality (Table 20) was not consistently affected by rearing treatment. One of the imported strains (HB) was severely affected by MD and the CB strain also experienced deaths associated with MD. Both these strains had a somewhat higher mortality rate when fed the high density diet.

Table 20. Mortality in the rearing phase (5-16 weeks of age)

Rearing diet	Strain: IB	HB	HT	CB	Mean
High density	0.44	25.88	4.39	8.33	9.76
Low density	2.63	22.37	4.39	5.26	8.66
Mean	1.53	24.13	4.39	6.80	9.21
LSD (P<0.05)	5.02				2.51

Initial laying phase

Performance results for the initial laying phase appear in Tables 21 and 22. Three of the strains laid more eggs and converted feed to eggs more efficiently when reared on the "low" nutritional regimen than when reared on the "high" regimen, while the fourth strain (HB) responded in a contrary manner (Table 21). However, none of the differences between rearing treatments was significant for any of the strains.

The four strains differed from one another in respect of several characteristics (Table 21); in particular, strains IB and HT laid more eggs than strains HB and CB ($P<0.05$); egg mass output of strains IB and HB was greater than that of HT ($P<0.001$) which was greater than that of CB ($P<0.001$); HB laid larger eggs than IB ($P<0.05$), which laid larger eggs than HT or CB ($P<0.001$); IB and CB ate more feed than HB or HT ($P<0.001$); CB converted feed to eggs less efficiently than the other strains ($P<0.001$); and mortality of HB was higher than that of CB ($P<0.001$) which was higher than that of HT ($P<0.05$).

Table 21. Effect of rearing treatment on performance in the initial laying phase

Strain	Rearing treatment	Eggs: number	Eggs: %	Down-grades %	Egg mass g/day	Egg wt g	Feed g/day	FCR g/g	Mortality %
IB	Low	254.34	75.70	5.12	47.128	62.26	112.06	2.3777	22.53
	High	247.80	73.75	4.89	45.597	61.83	110.42	2.4217	14.43
	Mean	251.07	74.72	5.01	46.363	62.04	111.24	2.3997	18.48
HB	Low	234.31	69.73	4.55	44.706	64.11	103.46	2.3142	63.44
	High	240.55	71.59	4.38	46.007	64.26	105.27	2.2881	46.32
	Mean	237.43	70.66	4.47	45.356	64.19	104.36	2.3011	54.88
HT	Low	253.45	75.43	5.58	43.116	57.16	102.00	2.3658	14.04
	High	249.94	74.39	5.13	42.239	56.78	102.20	2.4195	14.62
	Mean	251.69	74.91	5.36	42.678	56.97	102.10	2.3926	14.33
CB	Low	235.63	70.13	6.00	39.824	56.79	111.70	2.8050	20.04
	High	231.57	68.92	5.92	38.956	56.52	112.01	2.8753	25.23
	Mean	233.60	69.52	5.96	39.390	56.66	111.86	2.8401	22.64
LSD (P<0.05)		10.20	3.04	1.52	1.62	0.96	3.58	0.140	5.61
Rearing treat. means	Low	244.43	72.75	5.31	43.69	60.08	107.31	2.4657	30.01
	High	242.47	72.16	5.08	43.20	59.85	107.47	2.5012	25.15
LSD (P<0.05)		5.10	1.52	0.76	0.81	0.48	1.79	0.070	2.81

The higher dietary protein and linoleic acid levels tended to result in higher egg weights and egg mass output than the lower levels of these nutrients (Table 22). These effects were greater in the first half of the laying phase than in the second half. The effects of protein and linoleic acid on egg weight were additive in all strains except HT. In this strain, increasing both the lysine and the linoleic acid levels produced no further improvement in egg weight compared with increasing the level of either nutrient alone. On the other hand, in strain HT egg number and egg mass output appeared to respond additively to these nutrients. In strains IB and HB, the highest rates of lay were achieved with the low levels of protein and linoleic acid, while egg mass output was lowest and feed conversion poorest on the low protein high linoleic acid diet. Feed conversion of all strains was optimised with the high/high diet, though within-strain differences were not significant.

In the laying period the HB strain suffered severe losses and these were greater in the group that had been given the low density diet in the rearing phase. The other imported strain (IB) showed a similar trend. However, the laying period mortality of the two local strains appeared to be unaffected by rearing treatment. Mortality of strains HB and CB, which were affected by MD, was lower (P<0.05) on the low protein low linoleic acid layer diet than on other diets.

Table 22. Effect of dietary protein and linoleic acid on performance in the initial laying phase

Protein	Linoleic acid	Eggs: number	%	Down-grades %	Egg mass g/day	Egg wt g	Feed g/day	FCR g/g	Mortal-ity %
Strain IB									
Low	Low	254.16	75.64	5.65	46.420	61.37	111.36	2.3989	16.7
Low	High	248.09	73.84	5.82	45.952	62.23	113.01	2.4593	15.6
High	Low	252.30	75.09	4.06	46.567	62.02	110.54	2.3737	20.8
High	High	249.98	74.40	4.49	47.259	63.52	110.09	2.3295	20.8
Strain HB									
Low	Low	246.79	73.45	3.54	46.533	63.35	107.54	2.3111	49.7
Low	High	232.29	69.13	5.36	43.896	63.49	101.97	2.3230	57.9
High	Low	231.87	69.01	4.79	44.746	64.84	103.33	2.3092	54.8
High	High	238.76	71.06	4.18	46.251	65.09	104.61	2.2618	57.1
Strain HT									
Low	Low	246.19	73.27	4.83	41.124	56.13	100.17	2.4357	17.7
Low	High	251.46	74.84	5.04	42.998	57.45	102.06	2.3736	14.6
High	Low	250.94	74.68	5.57	42.983	57.55	103.39	2.4054	9.4
High	High	258.19	76.84	5.99	43.966	57.22	102.61	2.3338	15.6
Strain CB									
Low	Low	230.69	68.66	5.44	38.630	56.26	111.86	2.8955	12.5
Low	High	234.92	69.92	7.30	39.635	56.69	112.12	2.8288	20.8
High	Low	238.26	70.91	5.17	40.258	56.77	112.96	2.8060	30.2
High	High	230.57	68.62	5.93	39.459	57.50	110.50	2.8005	27.1
LSD (P<0.05)		14.43	4.29	2.14	2.28	1.36	5.07	0.198	8.0
Diet means									
Low	Low	244.46	72.76	4.87	43.177	59.28	107.73	2.5103	24.2
Low	High	241.69	71.93	5.88	43.120	59.97	107.29	2.4962	27.2
High	Low	243.34	72.42	4.90	43.639	60.30	107.56	2.4736	28.8
High	High	244.38	72.73	5.15	44.234	60.83	106.95	2.4314	30.2
LSD (P<0.05)		7.22	2.15	1.07	1.14	0.68	2.53	0.099	4.0
Protein means									
Low		243.07	72.34	5.37	43.149	59.62	107.51	2.5032	25.7
High		243.86	72.58	5.02	43.936	60.56	107.25	2.4525	29.5
LSD (P<0.05)		5.10	1.52	0.76	0.808	0.48	1.79	0.700	2.8
Linoleic acid means									
Low		243.90	72.59	4.88	43.408	59.79	107.64	2.4919	26.5
High		243.03	72.33	5.51	43.677	60.40	107.12	2.4638	28.7
LSD (P<0.05)		5.10	1.52	0.76	0.808	0.48	1.79	0.700	2.8

Average specific gravities for the strains were: IB 1.0836, HB 1.0803, HT 1.0769, CB 1.0768, with a least significant difference (LSD, $P<0.05$) between strains of 0.0028. Specific gravities of feeding treatments were not significantly different from one another.

Moult inducement period

As a result of feeding barley, production of all four strains fell below 5% within one week and a heavy moult was initiated. The intake of barley, however, varied with both strain and diet (Table 23). The imported strains ate less barley than the local strains ($P<0.05$), and birds that had previously been given the diets with the higher protein content ate less barley than those given the low protein diets (significant for IB and HT strains).

Table 23. Effects of strain and pre-moult diet on barley intake and percentage weight loss

Strain	Barley intake (g/day)	Body wt loss (%)	Pre-moult diet	Barley intake (g/day)	Body wt loss (%)
IB	20.3	22.0	low/low	29.4	20.1
HB	17.0	19.8	low/high	33.1	17.3
HT	33.6	18.1	high/low	23.5	21.4
CB	37.3	17.9	high/high	26.7	19.1
LSD ($P<0.05$)	8.3	4.7		7.6	4.5

The very low average barley intake of the imported strains appeared to be due to many individuals refusing to eat any barley at all throughout the 18-day period. The differences in barley intake had only a small effect on body weight loss, which averaged 19.5%. Control birds given normal feed continued to eat and lay normally and maintained normal body weight during this period.

Recovery period

Upon returning to full feed, all four strains resumed lay fairly quickly, achieving peak rates of lay between 81% and 85% four to seven weeks after the end of the barley feeding period. The speed and strength of this recovery were influenced by the diet fed in the 23-day recovery period (Figure 3), but not by the dietary treatments applied in the first laying cycle. Birds given diet D during the recovery period (treatments 3 and 6) peaked at approximately 83-85% between four and six weeks post-moult, while those given diet A (treatments 2, 4 and 5) peaked at approximately 81-83% between six and seven weeks post-moult. At this stage the rate of lay of the unmoulted control birds averaged 68-73%.

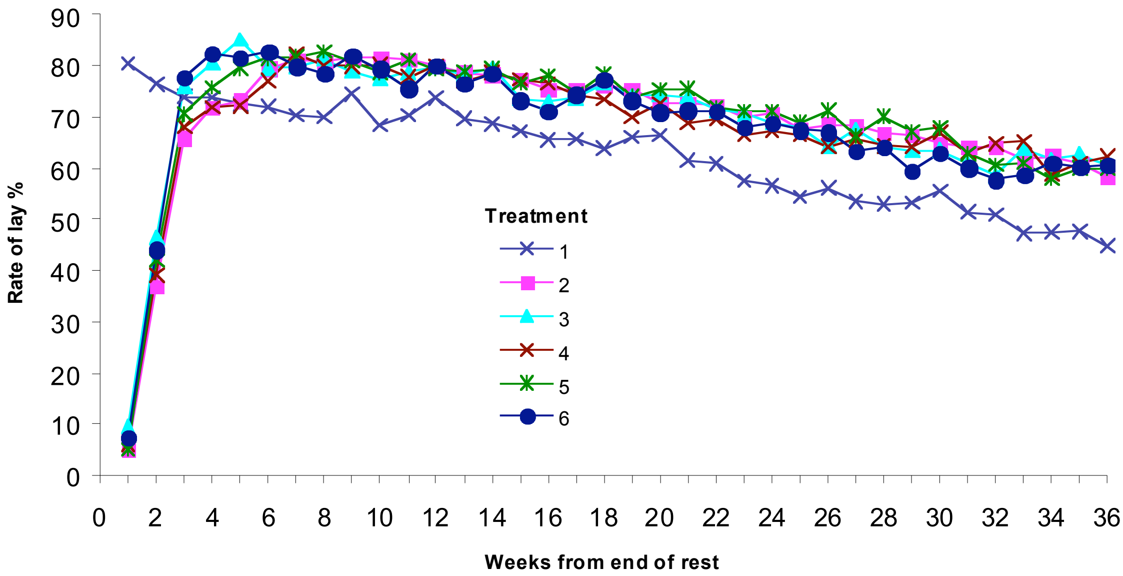


Figure 3. Rate of lay of second-cycle treatment groups (average of all strains) in the recovery and post-recovery periods

Recovery diet mean results for the 23-day period are shown in Table 24. (It should be noted, however, that the effects of the recovery diets appeared to extend for up to three weeks beyond this period.) Birds given diet D (high protein, high linoleic acid) laid larger eggs, ate more food, gained more weight and produced fewer defective eggs in the recovery period than birds given diet A (low protein, low linoleic acid; P<0.05). Intermediate body weight records show that the imported strains recovered weight more rapidly than the local strains.

In the recovery period, average egg specific gravities for the strains were: IB 1.0761, HB 1.0762, HT 1.0735, CB 1.0748, with a least significant difference (P<0.05) between strains of 0.0034. The egg specific gravity of moulted birds was not significantly higher than that of unmoulted birds, but moulted birds given the diet with higher levels of protein and linoleic acid had higher egg specific gravities (average 1.0759) than those given the lower quality diet (1.0724, P<0.05).

Table 24. Second-cycle treatment results for the 23-day recovery period (average of strains IB, CB and HT)

Treat-ment	Diet	Rate of lay (%)	Egg wt(g)	Egg mass (g/day)	Feed (g/day)	Feed/egg ratio	Body wt gain (%)
Control	B	76.1	62.16	47.47	111.5	2.347	0.6
Moulted	A	41.5	60.03	24.95	105.6	4.234	14.8
Moulted	D	46.8	62.20	29.15	113.9	3.907	17.9
LSD (P<0.05)		5.6	1.75	4.44	4.5	0.336	2.8

Post-recovery period

Response of strains to moulting

Table 25 shows the early response of each strain to moulting (this is a guide only, as different dietary regimens are represented in the moulted and unmoulted groups). The increase in egg production due to moulting was considerably greater in the local strains than in the imported strains; however, the average rate of lay of the unmoulted imported strains was similar to that of the moulted local strains. Mean egg weight was not increased by moulting: inspection of strain-by-treatment data shows that the apparent advantage, particularly in the IB strain, indicated in Table 25 is largely associated with the difference in linoleic acid levels between the control diet and one of the diets used for the moulted birds. In three of the four strains the percentage of downgraded eggs (mainly shell defects and breakages) was reduced by moulting. The result for HB is unclear as the observations for candled eggs are contradicted by the (less reliable) observations made at the point of egg collection. The trends that developed in the first four months post-moult continued to the end of the trial and are reflected in the results shown in Table 26.

Table 25. Strain results for the first four months of the post-recovery period - unmoulted control birds (treatment 1) compared with moulted birds (mean of treatments 2, 4 and 5)

Strain/ treat	Rate of lay (%)	Downgrades(%)* A	B	Egg wt (g)	Egg mass (g/day)	Feed (g/day)	Feed/egg ratio
IB control	75.9	3.8	15.0	65.78	49.90	112.5	2.255
IB moulted	80.5	3.7	9.4	67.59	54.45	117.9	2.167
HB control	72.2	5.0	9.5	68.02	49.13	111.7	2.274
HB moulted	79.9	1.7	10.2	68.13	54.42	114.8	2.111
HT control	65.5	4.0	17.0	62.93	41.19	98.6	2.393
HT moulted	76.3	1.4	10.5	62.56	47.70	105.1	2.204
CB control	63.4	4.5	11.5	60.36	38.25	107.3	2.806
CB moulted	74.8	2.2	8.5	61.23	45.78	117.4	2.565

* A: Defects observed at time of egg collection
B: Defects observed by candling

Effects of second-cycle treatments

The results in Table 26 include treatment mean results with and without strain HB, which was not represented in treatments 3 and 6. These results show that there were few substantial differences between any of the dietary treatments 2-6 in respect of most of the parameters studied. However, the mean egg weight of birds in treatments 5 and 6, which were given diet D (high protein and linoleic acid content) in the post-recovery period, was higher than that of birds on treatments 2 and 3 (diet B, medium-low protein, low linoleic acid), resulting in a slight improvement in egg mass yield and feed efficiency. The within–strain comparisons between diets fed in the post-recovery period indicated that strain HB responded more strongly than other strains to linoleic acid (eggs were approximately 2g heavier at the higher level) and protein (4% higher rate of lay at the higher level).

Table 26. Performance in the post-recovery period (refer to Methods for treatment descriptions)

Treat-ment	Eggs: number	Eggs: %	Downgrades* A%	Downgrades* B%	Egg mass: kg	Egg mass: g/day	Egg wt g	Feed: kg	Feed: g/day	FCR g/g	Mortal-ity %
Strain IB:											
1	140.99	62.94	7.55	18.46	9.429	42.09	66.88	24.86	111.0	2.637	4.06
2	157.96	70.52	5.22	15.38	10.607	47.35	67.15	26.08	116.4	2.459	10.63
3	163.91	73.17	7.45	13.92	10.945	48.86	66.77	26.36	117.7	2.408	2.50
4	154.67	69.05	5.63	11.42	10.494	46.85	67.85	25.38	113.3	2.418	5.36
5	163.22	72.86	7.01	14.66	11.280	50.36	69.11	26.52	118.4	2.351	7.81
6	159.28	71.10	6.64	14.65	10.924	48.77	68.58	24.88	111.0	2.277	1.79
Mean	156.67	69.94	6.58	14.74	10.613	47.38	67.74	25.68	114.7	2.420	5.36
Strain HB:											
1	139.12	62.11	7.09	11.69	9.499	42.41	68.28	25.14	112.2	2.647	2.78
2	154.14	68.81	4.17	11.18	10.366	46.28	67.25	24.99	111.6	2.411	4.64
4	160.16	71.50	3.60	14.81	11.101	49.56	69.31	24.75	110.5	2.230	10.66
5	167.02	74.56	4.06	11.38	11.633	51.93	69.65	25.75	114.9	2.213	0.00
Mean	156.25	69.75	4.59	12.33	10.739	47.94	68.73	25.16	112.3	2.343	4.64
Strain HT:											
1	127.91	57.10	4.82	20.28	8.121	36.25	63.49	22.24	99.3	2.739	6.99
2	151.92	67.82	2.52	14.11	9.494	42.39	61.20	23.66	103.7	2.492	9.39
3	154.31	68.89	3.02	13.56	9.663	43.14	62.62	23.72	105.9	2.454	11.99
4	147.18	65.71	3.26	16.50	9.220	41.16	62.65	22.56	100.7	2.447	11.07
5	150.48	67.18	2.64	12.83	9.546	42.61	63.43	22.93	102.4	2.403	7.14
6	146.37	65.34	3.16	18.54	9.236	41.23	63.10	22.34	99.7	2.419	12.22
Mean	146.90	65.58	3.24	15.96	9.247	41.28	62.95	23.00	102.7	2.487	9.80
Strain CB:											
1	123.22	55.01	7.91	18.25	7.572	33.80	61.45	24.26	108.3	3.204	10.27
2	153.54	68.54	4.45	10.85	9.482	42.33	61.76	26.08	116.4	2.750	11.83
3	144.32	64.43	6.32	13.61	8.742	39.03	60.57	25.47	113.7	2.913	1.56
4	148.80	66.43	3.29	7.61	9.260	41.34	62.23	26.10	116.5	2.819	12.62
5	146.29	65.31	5.56	12.36	9.050	40.40	61.87	25.00	111.6	2.762	8.85
6	151.61	67.68	7.42	13.15	9.494	42.38	62.62	26.54	118.5	2.795	8.34
Mean	144.62	64.56	5.82	12.63	8.933	39.88	61.77	25.58	114.2	2.863	8.91
LSD[1]	9.79	4.37	3.23	4.98	0.695	3.10	2.11	0.83	3.7	0.248	7.87
Feeding treatment means excluding strain HB											
1	130.71	58.35	6.76	19.00	8.374	37.38	63.94	23.79	106.20	2.860	7.11
2	154.47	68.96	4.06	13.45	9.861	44.02	63.37	25.27	112.17	2.567	10.62
3	154.18	68.83	5.60	13.70	9.783	43.68	63.32	25.18	112.43	2.592	5.35
4	150.22	67.06	4.06	11.84	9.658	43.12	64.24	24.68	110.17	2.561	9.68
5	153.33	68.45	5.07	13.28	9.959	44.46	64.80	24.82	110.80	2.505	7.94
6	152.42	68.04	5.74	15.45	9.885	44.13	64.77	24.59	109.73	2.497	7.45
LSD[2]	5.65	2.52	1.86	2.87	0.401	1.79	1.22	0.98	2.13	0.143	4.54
Feeding treatment means including strain HB											
1	132.81	59.29	6.84	17.17	8.655	38.64	65.02	24.12	107.70	2.807	6.24
2	154.39	68.92	4.09	12.88	9.987	44.59	64.34	25.20	112.02	2.528	9.27
4	152.70	68.17	3.94	12.59	10.019	44.73	65.51	24.70	110.25	2.479	9.93
5	156.75	69.98	4.82	12.81	10.377	46.33	66.02	25.05	111.82	2.432	5.95
LSD[3]	6.66	2.95	2.04	2.98	0.496	2.21	1.36	0.52	2.32	0.151	4.67

*A - downgrades observed at time of egg collection; B - downgrades observed by candling.
[1]LSD ($P<0.05$) strain x feeding treatment means (excluding strain HB)
[2]LSD ($P<0.05$) feeding treatment means (excluding strain HB)
[3]LSD ($P<0.05$) feeding treatment means (including strain HB)

The effect of the recovery diets on post-recovery performance may be assessed by comparing (in Table 26) treatment 2 with treatment 3, and treatment 5 with treatment 6, a comparison which excludes strain HB (see Methods). For all strains combined there are clearly no differences for any of the parameters studied. In the CB strain however, egg number and weight were depressed by treatment 3 ("high" recovery diet) compared with treatment 2 ("low" recovery diet), while in the HT strain mean egg weight was 1.4g higher on treatment 3 than on treatment 2.

Effects of first-cycle treatments on second–cycle performance

There were no substantial effects of the treatments applied before 64 weeks of age on performance after that age. However, birds that had received the lower protein level in the first cycle tended to produce heavier eggs in the second cycle (whether or not they had actually been moulted). Moulted birds that had received the diet containing the low protein and high linoleic acid combination in the first cycle tended to exhibit a lower rate of lay, lower egg mass, higher feed intake and poorer feed conversion in the second cycle than moulted birds that had received other diets in the first cycle. Some of these differences were significant ($P<0.05$) for some strains, though in a random way which suggests they were of doubtful biological significance.

Terminal post-mortem examination

Autopsies at termination of the trial revealed no abnormalities except for emaciation and/or egg binding in two birds. Strain HT carried less abdominal fat than strain IB or HB ($P<0.05$) and birds on post-moult treatment 6 carried more abdominal fat than those on treatments 1, 3, 4 or 5.

Table 27. Abdominal fat pad weight as percentage of bodyweight

Strain	IB		HB	HT		CB	LSD
Fat pad %	6.35		5.29	4.88		6.36	1.01
Pre-moult treatment							
(protein/linoleic)	Low/low		Low/high	High/low		High/high	LSD
Fat pad %	5.51		5.50	5.95		5.92	1.01
Post-moult treatment	1	2	3	4	5	6	LSD
Fat pad %	5.51	6.04	5.22	5.21	5.39	6.96	1.23

Economics

A financial assessment of major results was carried out using the following four egg-price structures:

"Low"	–	low price/kg, oversized eggs (>73g) not penalised.
"High"	–	high price/kg, oversized eggs classed as downgrades ("second quality").
"Flat"	–	medium price/dozen, same price all grades, oversized eggs not penalised.
"Scaled"	–	low price/kg for small eggs increasing to a high price/kg for very large eggs, oversized eggs not penalised.

"Low" egg prices were set at $1.80/kg for first quality eggs and $0.70/kg for downgrades and eggs under 45g. "High" egg prices were set at $2.80/kg for first quality and $1.00/kg for downgrades, eggs under 45g and eggs over 73g. "Flat" egg prices were set at 13.2 cents/egg ($1.58/dozen) for first quality and $0.80/kg for downgrades and eggs under 45g. The "scaled" egg price structure applied different prices to different Queensland grades as follows: Medium $1.90, Large $2.20, Extra Large $2.50, Jumbo $2.80/kg, downgrades $0.80. Feed was costed according to its ingredient composition using the following prices ($/tonne): wheat 180, sorghum 150, millrun 220, soybean (44%) 500, soybean (48%) 540, sunflower meal 230, cottonseed meal 275, meat and bone meal 480, blended vegetable oil 1500, limestone 85, dicalcium phosphate 650, salt 205, electrolytes 620, lysine 2950, methionine 5200. $55/tonne was added to cover the cost of vitamins, minerals, yolk pigment, milling and mixing and transport. The average daily margin of egg income over feed cost per bird was calculated, *not taking into account mortality*, which was largely influenced by non-experimental factors. Fixed costs, including pullet cost, were left out of account (as the daily depreciation rate varies with mortality rate and the length of time a flock is kept). Results are presented in Tables 28-31.

Table 28. Trial 1: Effects of strain, rearing treatment and layer diet on average financial margin (cents/bird/day) in the initial laying phase (Table 14 data, Table 5 diets)

Strain-Rearing treatment-Laying diet	Low price/kg egg	High price/kg egg, oversized eggs penalised	Flat price/dozen eggs	Scaled prices, (higher/kg for larger eggs)
IB-Advanced-Low	5.119	9.976	7.395	7.526
IB-Normal-Low	4.852	9.487	6.408	7.819
IB-Delayed-Low	4.759	9.285	6.257	7.650
IB-Normal-High	5.254	10.18	6.815	8.535
LB-Advanced-Low	5.078	9.840	7.165	7.611
LB-Normal-Low	4.889	9.520	6.383	7.934
LB-Delayed-Low	4.729	9.217	5.940	7.994
LB-Normal-High	4.800	9.405	6.164	7.978
ST-Advanced-Low	3.969	8.004	6.382	5.472
ST-Normal-Low	4.137	8.310	6.030	6.278
ST-Delayed-Low	4.014	8.090	5.785	6.155
ST-Normal-High	4.213	8.441	6.238	6.294
CB-Advanced-Low	3.769	7.791	6.211	5.240
CB-Normal-Low	3.853	7.964	5.490	6.182
CB-Delayed-Low	3.739	7.758	5.427	5.925
CB-Normal-High	3.517	7.526	5.510	5.367
Mean-Advanced-Low	4.517	8.916	6.837	6.477
Mean-Normal-Low	4.426	8.859	6.072	7.033
Mean-Delayed-Low	4.314	8.666	5.853	6.918
Mean-Normal-High	4.457	8.966	6.197	7.025

The results for Trial 1 (Table 28) show that the Advanced rearing treatment gave the highest daily average return for the "imported" layer strains under all except the Scaled egg price structure, while for the local strains the Normal rearing treatment gave the highest return except under the Flat rate structure, when the Advanced treatment was best. For the IB strain the high specification layer diet provided a better return than the low diet under all price structures, but other strains appeared to be indifferent as to diet quality, with the CB strain normally producing best results on the lower quality diet. The imported strains invariably provided higher returns than the local strains regardless of husbandry and egg price structure.

Table 29. Trial 2: Effect of rearing treatment on average financial margin (cents /bird/day) in the initial laying phase (Table 21 data, average of Table 8 diets)

Strain	Rearing treatment	Low price/kg egg	High price/kg egg, oversized eggs penalised	Flat price /dozen eggs	Scaled prices, (higher/kg for larger eggs)
IB	Low	4.414	8.719	5.658	7.366
	High	4.235	8.455	5.496	7.025
	Mean	4.324	8.566	5.575	7.193
HB	Low	4.339	8.312	5.241	7.471
	High	4.522	8.621	5.455	7.778
	Mean	4.430	8.466	5.347	7.624
HT	Low	3.962	7.714	5.806	5.815
	High	3.848	7.543	5.725	5.612
	Mean	3.910	7.636	5.773	5.719
CB	Low	3.076	6.520	4.754	4.724
	High	2.923	6.290	4.586	4.495
	Mean	2.994	6.398	4.661	4.604
Rearing treat. means	Low	3.948	7.816	5.365	6.344
	High	3.883	7.727	5.316	6.228

In the initial laying phase of Trial 2 (Table 29), imported strains gave better daily average returns than local strains under all except the Flat egg price structure, when strain HT gave the highest return. For three of the strains, the low specification rearing diet (with some feed restriction) resulted in consistently better returns than the high specification diet, while for the fourth strain (HB) this situation was reversed. Under all price structures, the IB and CB strains tended to give higher returns with the higher protein layer diets (Table 30). On average, linoleic acid had a strongly depressing effect on financial returns, especially in the CB strain which showed a higher margin with the lower concentration of linoleic acid under all price structures. However the result for CB may be influenced by the rather high percentage of downgraded eggs in the low protein/high linoleic acid treatment.

Table 30. Trial 2: Effects of protein and linoleic acid on average financial margin (cents/bird/day) in the initial laying phase (Table 22 data, Table 8 diets)

Strain	Protein	Linoleic acid	Low price/kg egg	High price/kg egg, oversized eggs penalised	Flat price /dozen eggs	Scaled prices, (higher/kg for larger eggs)
IB	Low	Low	4.494	8.744	5.823	7.229
	Low	High	4.053	8.208	5.215	6.901
	High	Low	4.573	8.891	5.889	7.485
	High	High	4.306	8.610	5.389	7.514
HB	Low	Low	4.869	9.163	6.001	8.033
	Low	High	4.110	8.057	5.026	7.053
	High	Low	4.400	8.363	5.187	7.649
	High	High	4.355	8.363	5.186	7.781
HT	Low	Low	3.961	7.458	5.893	5.582
	Low	High	3.959	7.621	5.784	5.870
	High	Low	3.986	7.617	5.761	5.899
	High	High	3.802	7.492	5.671	5.694
CB	Low	Low	3.150	6.405	4.859	4.680
	Low	High	2.839	6.088	4.430	4.434
	High	Low	3.267	6.678	5.020	4.946
	High	High	2.805	6.119	4.355	4.545
Diet means	Low	Low	4.134	7.832	5.676	6.359
	Low	High	3.747	7.383	5.129	6.051
	High	Low	4.063	8.122	5.479	6.479
	High	High	3.816	7.916	5.156	6.345
Protein means	Low		3.941	7.927	5.402	6.205
	High		3.940	8.019	5.319	6.411
Linoleic acid means		Low	4.100	8.138	5.578	6.419
		High	3.781	7.809	5.143	6.197

In the second laying cycle, egg price structure had little influence on the relative economic performance of the dietary treatments (Table 31). Following an induced moult, treatments 5 and 6, which utilised the diet with the highest protein and linoleic acid content after the initial recovery phase, generally gave lower returns than the other treatments. Returns were most often optimised with diet B, which had low levels of both protein and linoleic acid.

Table 31. Trial 2: Effects of feeding treatment on average financial margin (cents/bird/day) in the post-recovery period (Table 26 data, Table 9 diets; refer to Methods for treatment descriptions)

Strain	Treatment	Low price/kg egg	High price/kg egg, oversized eggs penalised	Flat price /dozen eggs	Scaled prices, (higher/kg for larger eggs)
IB	1	2.501	5.232	2.117	5.335
	2	3.417	6.466	3.410	6.786
	3	3.772	7.232	3.955	7.254
	4	3.653	6.912	3.737	7.280
	5	3.217	5.984	3.090	7.169
	6	3.241	6.189	3.128	6.981
	Mean	3.291	6.381	3.236	6.786
HB	1	3.227	5.954	3.092	6.563
	2	3.887	7.120	4.043	7.383
	4	3.729	6.442	3.539	7.644
	5	3.986	7.061	3.983	8.337
	Mean	3.765	6.807	3.720	7.579
HT	1	1.884	4.441	1.469	3.875
	2	3.208	6.623	3.684	5.418
	3	3.314	6.781	3.846	5.790
	4	2.652	5.802	2.893	4.924
	5	2.842	6.260	3.276	5.431
	6	2.141	5.142	2.196	4.411
	Mean	2.657	5.846	2.896	4.994
CB	1	1.485	4.026	1.302	3.173
	2	3.186	6.775	3.962	5.576
	3	2.478	5.666	3.058	4.441
	4	3.115	6.758	3.973	5.621
	5	2.252	5.598	2.818	4.503
	6	2.230	5.659	2.747	4.676
	Mean	2.442	5.732	2.975	4.643
Feeding treat. means excluding strain HB	1	1.955	4.654	1.628	4.101
	2	3.277	6.773	3.687	5.921
	3	3.193	6.647	3.625	5.800
	4	3.138	6.562	3.534	5.915
	5	2.782	6.229	3.065	5.676
	6	2.530	5.827	2.688	5.316

DISCUSSION OF RESULTS

The results of the trials are discussed below in relation to the Project objectives.

Rearing methods

An objective of Trials 1 and 2 was to provide ways of advancing or delaying the maturity of pullets so as to modify their subsequent laying performance to take advantage of market conditions. It was assumed that the differing characteristics of local and "imported" strains of bird might require different approaches to rearing management.

On the question of technique, a comparison of the results of Trials 1 and 2 suggests that simple nutritional methods alone, conducted within ethically acceptable limits, provide less control over subsequent performance of imported laying stock than a combination of lighting and feeding techniques. Although in Trial 2 the onset of lay was delayed by ten to twelve days by using a low density diet together with mild feed restriction (as compared to a high density diet fed *ad libitum*), the resultant small improvements in egg number and egg weight achieved with three of the strains were not significant, while one of the imported strains appeared to be adversely affected by this treatment. The economic analysis of Trial 2 reflects the biological results. On the other hand the techniques employed in Trial 1, which included changes in daylength, achieved differences in age at maturity of 30 to 41 days, and these profoundly affected subsequent laying performance. The advanced birds laid more but smaller eggs than the normally reared birds while the delayed birds laid somewhat fewer eggs, with one strain (LB) laying larger eggs. The economic analysis of Trial 1 suggests under most price structures local strains should be "normally" reared while imported strains should achieve best returns when reared to bring them into lay at an early age. Approaching the end of the initial laying phase, egg production and feed conversion tended to be poorer for the advanced birds than the normal and delayed birds. This trial, however, had a shortened laying period and it is not safe to predict, from performance towards the end of this period, the probable outcome over a more extended period of lay, as production at this time may have been influenced by the impending disease problem. The fact that the delayed birds in Trial 1 tended to exhibit a different production response to the delayed birds in Trial 2 indicates that it is not possible to predict laying performance on the basis of relative age at maturity and bodyweight alone, but that the *method* of delaying the onset of lay may need to be taken into account.

Although the incidence of MD was high in certain strains in both trials, the influence of the rearing treatments on mortality of MD-affected birds was different in the two trials, with one suggesting that a poor nutritional regimen during rearing increases mortality in the growth phase and reduces it in the laying phase, while the other suggested the opposite effect. The difference may be explained in part by the different physiological condition of the two flocks: in the first trial the birds tended to be overweight at maturity while in the second trial they were somewhat underweight. Also the two flocks were reared at different times of year. The lighting treatments applied in the first trial may also have influenced the results. Thus the two trials together neither support nor confute previous findings with MD-affected flocks, but point to a "play it safe" policy of meeting recommended target weights.

Layer diets in the first production cycle

Another objective of Trials 1 and 2 was to ascertain the benefits, if any, of using high specification layer diets, particularly for "imported" layer strains, and particularly with regard to the effects of protein and linoleic acid on egg weight. The principal rationale of Trial 2 was to find a balance of protein and linoleic acid that would support maximum egg numbers while minimising the feeding cost associated with maintaining egg weight, which in the case of imported strains is too high for most markets.

In the first phase of Trial 1 the two experimental layer diets differed in energy content as well as protein, but the higher density diet also had a higher ratio of protein to energy.

There were no consistent differences in performance between these diets other than a reduction in feed intake and concomitant improvement in feed conversion with the high density diet. Of special interest was the question whether imported strains of layer would perform more efficiently on the higher specification diet. The economic analysis indicates that at least one imported strain (IB) did produce better results on the high diet than on the low diet. The following comparison of nutrient intakes and cost of feeding shows that egg mass output increased in line with energy intake, but the intake of other nutrients appeared to be excessive on the high specification diet. Nevertheless the extra cost of feeding the latter diet would be justified even if the net price received for eggs fell as low as $0.805/kg (approximately $0.58/dozen 60g eggs).

Daily nutrient intake, feeding cost and egg output of imported strains (mean of IB and LB):

Diet	**Feed g**	**Energy kJ**	**Lysine mg**	**Meth + Cys, mg**	**Linoleic acid, mg**	**Feeding cost, c**	**Egg mass**
Low	118.1	1321	850	649	1181	2.88	49.77
High	113.0	1362	949	757	2034	3.04	51.76
Ratio, high/low	0.957	1.031	1.116	1.166	1.722	1.055	1.040

The initial phase of Trial 2 compared low and high dietary concentrations of protein and linoleic acid in a factorial design, using approximately iso-energetic diets. (It should be mentioned, however, that the uses of the words “protein” and “linoleic acid” are nominal only. It is possible that only one or a small number of amino acids were responsible for the observed effects of “protein”, while in the case of linoleic acid it is possible that other factors associated with the provision of linoleic acid in the diet produced the effects which have been attributed to this nutrient). The results indicate that there was no effect of diet on egg number or feed intake, and while increasing either protein or linoleic acid generally resulted in small increases in egg weight, these increases were greater in the imported strains, where they were least needed. The economic analysis shows that under all price structures the high linoleic acid concentration was less profitable than the low concentration. On the other hand the IB strain consistently yielded better returns when given the higher protein diet, and while returns from the CB strain also tended to be higher on the high protein diet, this result may have been assisted by differences in the percentages of downgraded eggs.

Layer diets in the second production cycle

The post-moult phase of Trial 2 provides a case for using a high-specification diet for a short time immediately following the moult inducement period. Regardless of strain, birds given the higher quality diet (11.8MJ/kg, 178g/kg protein, 20g/kg linoleic acid) resumed production more rapidly than those given the lower quality diet (11.5MJ/kg, 145g/kg protein, 8.8g/kg linoleic acid). There is some evidence that the 23-day recovery period used in this trial was not long enough for the high-specification diet to maximise its effect, as birds in treatment 3 exhibited a sharp downturn from their peak rate of lay shortly after replacing this diet by one of lower specification (11.7MJ/kg, 156g/kg protein, 8.2g/kg linoleic acid).

Following the recovery phase, the only effect of using a high specification diet was to increase mean egg weight. While this may be advantageous when using local strains of bird, in most circumstances it would be a disadvantage when using imported strains due to the difficulty of handling and marketing very large eggs. Thus, after the initial recovery phase, a protein level of 156g/kg and linoleic acid level of 8.2g/kg throughout the remainder of the second cycle appeared to be adequate for egg numbers while keeping egg size to a minimum. The economic analysis strongly supports this, as using the diet containing 178g/kg protein and 20g/kg linoleic acid resulted in a substantially depressed financial margin under all egg price structures. The biological and economic results of Trial 2 also suggest that moulting (at 64 weeks of age) is of relatively greater value for local than for imported strains.

Relative effects of layer diets on egg egg weight

One of the objectives of the trials involving different dietary concentrations of protein and linoleic acid was to compare their effectiveness for manipulating egg weight. Results of Trial 2 indicate that on average (in the range of concentrations studied) a 10g/kg increase in protein or linoleic acid increased egg weight by the following amounts:

	Protein		**Linoleic acid**	
	First cycle	*Second cycle*	*First cycle*	*Second cycle*
Increase in egg weight (g)	0.52	0.25	0.39	0.76
Increase in diet cost ($/tonne)	9.17	16.27	15.16	19.55
Approx. extra cost/egg (cents)	0.137	0.244	0.227	0.293
Approx. cost of increasing wt of one egg by 0.5g (cents)	0.132	0.488	0.291	0.193

This indicates that the most efficient way of increasing egg weight is by increasing the protein content of the diet in the first laying cycle, and the linoleic acid content in the second laying cycle. The biological results for protein in the first cycle are in line with those reviewed by Morris and Gous (1988). The results for linoleic acid are consistent with the finding of Mannion *et al.* (1992) that the response to this nutrient is greater in older birds. However the average effect of linoleic acid is not as large as that demonstrated in some research (Balnave, 1985; Mannion *et al.,* 1992), notwithstanding that other researchers deny the effect of linoleic acid on egg weight (e.g. Whitehead, 1983). Two factors that could account for differences between trials are the existence of strain differences (Mannion *et al.,* 1992, Leary *et al.,* 1998) and variation in the amount of linoleic acid stored in body tissues, for example due to different rearing diets (Whitehead, 1983). However, in Trial 2 there was no evidence of interactions between diets used in the initial laying phase, post-moult recovery period and post-recovery phase to suggest that body reserves of linoleic acid are of any significance. This point could be clarified by appropriate carcass analyses, which were not done in this trial.

Table 32 shows the projected differences in the grade mix (Queensland) produced by imported brown-egg strains at three different ages when given diets containing 8 or 28 g/kg linoleic acid. The figures are derived statistically from a model based on the results of Trial 2. The calculations assume that, for a flock of given age, the addition of linoleic acid to the diet would result in a similar percentage increase in weight over the whole range of egg weights.

Table 32. Expected grade mix of imported brown-egg strains given high and low linoleic acid diets (percentage eggs in each class, excluding second quality)

Age (wks)	Linoleic acid (g/kg)	Egg wt (g)	E <45	M 45-52	L 52-59	XL 59-66	J 66-73	OS >73
27	28	51.9	4.8	45.9	44.7	4.5	0.1	0.0
27	8	51.6	5.8	47.7	42.5	3.4	0.0	0.0
55	28	66.1	0.0	0.4	8.5	40.4	41.2	9.5
55	8	64.7	0.0	0.7	12.7	46.7	34.5	5.4
80	28	69.5	0.0	0.1	2.9	23.5	47.2	26.3
80	8	67.1	0.0	0.3	6.3	35.3	44.5	13.6

This example illustrates the potential to achieve substantial changes in the grade mix produced by ageing flocks of imported large-egg strains by altering dietary linoleic acid concentration. However the predicted effect in younger birds is much smaller. Finally, if the aim is to *minimise* egg size, then an advantage of reducing linoleic acid rather than protein level is that there is less risk of any adverse effect on egg number (Connor and Mannion, 1986).

Rejuvenation of diseased birds

An objective of trial 1 was to assess the value of moulting and different post-moult diets for layers exhibiting high or very low rates of lay prior to moulting due to an outbreak of AE. While this was primarily an evaluation of the ability of induced moulting to overcome the damaging effects of AE, information relevant to healthy birds (controls) was also provided. The results showed that the responses of normal and AE-affected (low producing) birds to subsequent management are very different. While the performance of the unaffected birds was improved by resting but showed little reaction to differences in nutrient density, the diseased birds failed to respond satisfactorily to the resting treatments but showed a markedly improved performance when given the higher density diet, in respect of egg number, egg weight and shell quality. The general health of the latter birds improved, resulting in higher feed intake and body weight gains when compared with diseased birds maintained on the low density diet. These results therefore indicate that birds which have suffered a severe set-back such as occurred in this instance require a high quality diet and will not be rejuvenated by resting.

IMPLICATIONS

The comparative economic value of the management strategies studied in this project have been outlined in the Results and Discussion and are summarised below in general terms.

The comparison of rearing treatments applied in Trials 1 and 2 and their effects on subsequent laying performance suggests that lighting programs are an indispensable component of rearing management. Nutritional rearing methods alone, conducted in an ethically acceptable manner, are probably insufficient to ensure maximum returns over a full production cycle. A specific implication of Trial 1 is that by adopting a rearing program which advances maturity, total egg numbers can be increased and mean egg weight reduced in the first nine months of lay. This may be economically advantageous for imported large-egg strains of layer.

Under most market conditions, imported brown-egg strains in their first laying cycle appear to require diets with a high (approximately 180g/kg) protein content and low (8-11g/kg) linoleic acid content to maximise profitability. In the second cycle a lower (approximately 150g/kg) protein diet is likely to be more economical under a wide range of egg price structures. For local strains there could be benefits from employing lower nutrient specifications (protein/amino acids) than those used in this project: a current project at QPRDC may shed some light on this possibility.

The rapidly increasing use of introduced large-egg strains of layer is profoundly altering the relative proportions of different egg grades (the “grade-mix”) produced on farms and reaching the market-place. While some markets have had little difficulty in adjusting to this change, in Queensland there has been a massive over-supply of the largest egg grades. The situation has not been helped by the continuing popularity of induced moulting. Management techniques such as those studied in this project provide only limited means of aligning the grade-mix produced on a farm with the saleable grade mix. It is therefore suggested that either of two alternative approaches to the problem might be more effective: (a) foster the market for large brown eggs or (b) import strains of bird which are better able to supply local needs.

Results from this project also indicate that birds which have suffered a severe set-back causing loss of production, as was experienced in Trial 1, require a high quality diet to assist recovery and will not be rejuvenated by induced moulting.

RECOMMENDATIONS

Recommendations resulting from this work are as follows.

To manipulate age at maturity and egg size, use lighting programs whenever possible instead of relying on feeding management. In circumstances where the scope for changing daylength over a period of time is limited, use a single-step change between nine and twelve weeks of age.

Both protein and linoleic acid content of the layer diet may be altered to manipulate egg weight. Since sensitivity of egg weight to linoleic acid appears to increase with increasing age of bird, the economics of using linoleic acid would be expected to be less favourable than with protein in the first laying cycle but more favourable in the second cycle. However the monetary results from this project indicate that high dietary concentrations of linoleic acid are never economically advantageous. Therefore it is recommended to use a low (<10g/kg) linoleic acid allowance when formulating least cost diets.

Results from this trial suggest that, in circumstances where it is desirable to minimise egg weight, the most effective strategy is to bring the flock into lay early using a step-up lighting pattern together with a high specification grower diet, followed by a high specification layer diet until eggs reach a marketable weight, then a medium or high protein diet (160-180g/kg depending on strain) containing a minimum amount of linoleic acid (<10 g/kg). However, it is suggested that the employment of this or any similar strategy is no substitute for selecting a suitable strain of bird.

Following an induced moult, it is suggested that a high specification recovery diet should be fed at least until production has peaked. Thereafter all strains require a low specification diet (probably containing approximately 150g/kg protein).

Recovery from disease situations may be assisted by increasing the nutrient density of the diet. Induced moulting may impose an additional stress on a flock already weakened by disease; therefore recommendations to moult birds following disease problems should be considered with care.

COMMUNICATIONS STRATEGY

The main results from this project have been presented and published as conference proceedings and other articles (see Bibliography). A scientific paper is in preparation and this will be submitted to a refereed poultry science journal.

It is proposed to seek approval and funding for a one-year project in which the results of this and a number of other projects will be brought together to develop a complete model of layer performance, to simplify the decision-making process for the management and feeding of poultry.

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COMPENDIUM SUMMARY

Project Title

IMPROVEMENTS IN LAYING FLOCK MANAGEMENT TO OPTIMISE PERFORMANCE IN A CHANGING INDUSTRY.

Objectives

(i) To compare the profitability of early and late maturing strains of layer (including recently introduced strains) after advancing or retarding the onset of lay by feeding and husbandry techniques.

(ii) To study effects of nutrient density (Trial 1) and protein and linoleic acid level (Trial 2) in the laying diet, with particular reference to egg size of imported strains during first and second laying cycles.

(iii) To assess the response to induced moulting treatments and post-rest diets in local and introduced strains of layer exhibiting high or (as a result of an outbreak of avian encephalomyelitis, AE) very low rates of lay prior to moulting.

Background

Recent developments in the Australian poultry industry include the introduction of overseas strains of layer, the move to de-regulation and unrestricted trading between states and improvements in welfare standards for poultry. Compared with local strains of bird, the "imported" strains are generally more docile, lay much larger eggs, convert feed to eggs more efficiently and tend to be less resistant to disease organisms occurring in the Australian environment. It is therefore probable that different management standards and strategies are needed. Although breeding company recommended dietary specifications are higher than for local strains, these standards have been questioned. The increasing use of imported strains has caused surpluses of very large eggs in many areas, resulting in a need for the development of feeding and management strategies to overcome this problem. With reduced prices for the largest grades of eggs, the viability of keeping flocks for a second production cycle has been put in doubt, though modified husbandry techniques for moulted birds might improve this prospect. The kinds of rearing techniques advocated in the past for local strains have also tended to result in an increase in average egg weight, and some of these techniques are now ethically unacceptable. Different rearing methods may therefore be appropriate not only for imported strains but for the industry in general.

Development

Aspects of husbandry considered to be of greatest significance for recent developments in the industry were the husbandry of pullets in the rearing stage and nutritional requirements in the first and second laying cycles. Two long-term trials were conducted, each using two local and two "imported" strains of layer. Rearing stage experiments were designed with modified feed restriction procedures and lighting techniques, and in view of the need to reduce egg size of imported layers, treatments were included which were designed to hasten maturity. Treatments in the first laying cycle were aimed mainly at the problem of controlling egg size and included different nutrient densities and different combinations of dietary protein and linoleic acid. In Trial 1, second cycle treatments were designed to investigate the amelioration of disease effects originating in the first cycle, while in Trial 2 post-moult treatments included different recovery diets (fed for a short period following the moult) and different dietary concentrations of protein and linoleic acid, again with a view to controlling egg size.

Outcomes

It was found that average egg weight was markedly reduced and egg numbers were increased by the combined use of feeding and lighting techniques in the rearing period designed to hasten maturity. Conversely, egg weight tended to be increased at the expense of egg number when maturity was delayed. Feeding techniques alone during rearing, conducted within ethically acceptable limits, were not consistently efficient at controlling egg weight. High dietary protein concentrations were found to increase egg weight of most strains, particularly in the first laying cycle, and usually resulted in higher financial margins than low specification diets in the first laying cycle and substantially lower margins in the second laying cycle. High dietary linoleic acid concentrations also tended to increase egg size, but the effect was greater in the second laying cycle than in the first. For all strains of bird under most egg price structures, increasing the dietary linoleic acid reduced the daily average financial margin. The effects of protein and linoleic acid on egg weight were usually additive. Under most egg price structures the financial margin of the Isabrown strain was higher with a high (approximately 180g/kg) protein diet than with a lower protein diet but the financial margin of other strains was not clearly affected by protein level. Following an induced moult, birds given a high protein, high linoleic acid diet for a 23-day period returned to lay more rapidly and with larger eggs than those given a lower specification diet. In one trial, in which a proportion of the flock suffered a production setback due to AE, the affected birds were not rehabilitated by either of two moulting treatments. Control birds that were unaffected by AE responded positively to these treatments. A diet of high nutrient density greatly improved the rate of lay, egg weight, egg shell quality and bodyweight of the AE-affected birds, as compared to a low-medium density diet.

Implications

The results of the rearing experiments indicate that lighting programs are an indispensable component of rearing management. Nutritional manipulations alone, conducted in an ethically acceptable manner, are probably insufficient to ensure maximum returns over a full production cycle. A step-up lighting program together with a high specification grower diet increases total egg number and reduces mean egg weight in the first laying cycle. This may be economically advantageous for imported large-egg strains of layer.

Under most market conditions, the profitability of imported large-egg strains of layer may be improved by feeding a diet with a high protein content in the first laying cycle, a medium/low protein content in the second cycle and low linoleic acid content throughout lay. Other strains may not need a high protein diet in the first cycle. The rapidly increasing use of imported strains is profoundly altering the relative proportions of different egg grades produced on farms. Producers will be able to apply the findings of this project according to the strain of bird used and with a view to meeting changes in consumer demand for different egg grades so as to maximise returns. However, management techniques such as those studied here provide only limited means of aligning the grade-mix produced on a farm with the saleable grade-mix.

Birds that have suffered a severe set-back causing loss of bodyweight and production appear to require a high quality diet to assist recovery and are unlikely to be rejuvenated by induced moulting.

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