Energy requirements of layer strains

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Foreword

The relative cost of energy in poultry diets having different energy densities depends on the relative costs of low and high energy feed ingredients. The cost of feeding these diets, however, depends also on the effect that variations in dietary energy content have on feed intake of the birds, which in turn affects the levels of other expensive nutrients in the diet specification. The economic analysis of Morris (1968) suggests that correctly accounting for this variation could save about 0.2 cents/bird/day or 70 cents per annum. Furthermore the energy level of the diet may affect bird health and production. Although historical information relating mainly to white leghorn hybrids suggests that the energy level of the diet rarely affects any performance factor other than feed intake, little information is available on the responses of modern high-producing brown-egg layers to changes in dietary energy density. The bird's response to changes in dietary energy density may be affected by a number of factors, such as strain, age, body weight and condition of the bird, level of production, environmental conditions, feed form, supplementation with feed enzymes and other non-energy factors relating to the feed. Most of the earlier work on energy requirements was done with diets that undoubtedly varied in bulk and fibre content as well as energy level. There is a paucity of usable information on the relationships between dietary energy level and all these factors, particularly in relation to modern "imported" strains of layer when fed diets containing typically Australian ingredients such as sorghum, wheat, sunflower and meat meal. A rigorous characterisation of the relationships between dietary energy level, feed intake, energy "requirement" and the most important of these factors would be of considerable benefit to the stockfeed and egg industries throughout Australia.

The aim of the research is to precisely characterise the energy intake and requirement of IsaBrown and Hyline Brown layer strains in terms of dietary energy concentration, feed intake, egg output, body weight and body fat content. This will enable formulation of diets containing the most cost effective energy levels in different circumstances. Methods of utilising the results in LCF programs/data bases will be demonstrated.

The project objectives were achieved by conducting two trials using multi-bird and single-bird experimental units, apparent metabolisable energy (AME) studies, carcass composition studies and multiple regression analyses. Experiment 1 was a nine-month trial covering warm and cool seasons, using IsaBrown and Hyline Brown strains. Birds were fed wheat+sorghum based diets ranging from 11 to 12.2 MJ/kg in 0.3 MJ/kg increments (five AME levels). Two series of diets were used: (1) with bulk and fibre increasing as AME level declines (reflecting most previous studies in this area); (2) with bulk and fibre held constant (approx. 1.3 l/kg and 40g/kg respectively).

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This report is an addition to AECL's range of research publications and forms part of our R&D program, which aims to support improved efficiency, sustainability, product quality, education and technology transfer in the Australian egg industry.

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Executive Summary

When laying hens are allowed unlimited access to feed they tend to eat enough feed to satisfy their energy requirements. Many strains of layer, however, are far from perfect at judging their energy needs: they may under-consume diets with a low energy content and over-consume those with a high energy content. This not only results in the birds receiving too little or too much energy to support optimum health and performance, but, unless the nutrient profile of the diet is carefully matched to the birds' feed intake, shortages or wastage of many other nutrients occur, resulting in considerable economic loss. It has been shown that for commercial strains developed in Australia, overconsumption of energy may occur when the diet contains more than 12 MJ/kg metabolisable energy (ME). However, the "imported" brown-egg strains that have recently become extremely popular produce considerably more egg mass and generally convert feed to egg mass more efficiently than local strains, therefore, it may be that their nutritional requirements are more precise and that their response to changes in dietary energy content are different, particularly at the low end of the spectrum. The breeders' suggested energy levels are in the region of 11.5-12 MJ/kg, but there is no evidence to support these recommendations under Australian conditions.

The aim of this study was to find how variation in dietary energy concentration affects the performance of two imported brown egg layers (IsaBrown strain and Hyline Brown strain) housed in conventional two bird cages in the southeast Queensland environment.

Two main experiments were conducted, the first aimed mainly at measuring the effects of dietary AME level on feed intake, egg production and egg weight throughout the greater part of the laying period, the second aimed at establishing the relationships between dietary energy level, feed intake, energy intake, egg mass, bodyweight and bodyweight gain. (The required multivariate analysis is best achieved with individual bird data). Each of the two experiments used equal numbers of IsaBrown and Hyline Brown layers. The birds were reared on site in accordance with hatchery recommendations with respect to diet, lighting program and growth rate.

In a factorial randomised block design experiment, diets containing five metabolisable energy (ME) levels and two densities (fixed and floating) were fed to two bird strains (Isabrown and Hyline Brown) hens housed in two-bird cages. Each treatment combination was represented by six 8-bird replicates. The nominal ME values of the diets were 11.0, 11.3, 11.6, 11.9, 12.2 MJ/kg, while the ME values obtained by metabolism studies, using layers, were 10.32±0.21, 10.76±0.22, 11.20±0.20, 11.60±0.29, and 12.19±0.19MJ/kg for diets where density was allowed to floating and 10.78±0.26, 11.14±0.27, 11.50±0.26, 11.86±0.25, and 12.23±0.25/kg for diets where the density was fixed. Amino acids, total protein, calcium and phosphorus were maintained in approximate proportion to the nominal ME levels. The trial ran for 48 weeks (18 –66 weeks of age).

The results reported here are based on cumulative data from 18 to 66 weeks. Isa brown birds consumed less feed and energy, laid larger eggs and gained less weight than the Hy-line Brown birds (all $P<0.01$). The conversion of feed to egg mass was more efficient by Isa brown birds but this was just outside significance level ($P<0.056$). Each increase in dietary ME level resulted in decreased feed intake, increased energy intake and body weight gain and improved feed conversion (all $P<0.01$).Dietary ME had no effect on rate of lay, egg weight and egg mass. Diet density whether floating or fixed had an effect only in energy intake were birds on fixed density diets consumed more energy ($P<0.01$). There was also a trend toward increasing feed intake and body weight gain and improved feed conversion when birds were offered diets with fixed density ($P<0.05$).There were significant energy by density interactions for feed intake and feed efficiency ($P<0.05$).At the two lowest ME level

(10.3 and 10.8 MJ/kg), the floating density diets resulted in higher feed intake than the highest energy and float or fixed density diets. There was no difference in feed intake when diets were either fixed or floating and had an ME of 11.2 MJ/kg (120g/d) or 11.6 MJ/kg (115g/d). However, at the highest ME level (12.2 MJ/kg) birds on fixed density diet consumed 3g/d more feed than birds on floating density diet. The responses of the two strains to changes in dietary ME and density were quite similar for all parameters except body weight gain. With increasing ME, the differences between means for body weight change of Isa bird was 86g compared to 120g for Hy-line birds. The increase in energy intake with increasing dietary ME level was similar for both strains. However, there was little variation in energy intake with dietary ME levels in the range 10.8-12.2 MJ/kg for both strains.

Isa brown and Hy-line Brown strains were both efficient at adjusting feed intake to maintain energy intake when fed diets varying in ME content and either floating or fixed density over a limited range. Daily energy intake increased as the energy level of the diet increased even though daily feed consumption decreased as the energy level of the diet increased. Clearly, the birds were not able to fully compensate to a constant energy intake as the energy level of the diet increased. This extra energy intake did not influence bird performance. Both strains ‘over consumed’ energy when given diets containing 11.2 MJ/kg. A reasonable interpretation of the results is that changes in feed intake were mainly attributable to dietary ME level while diet density had little influence on feed intake. The apparent effect of density on other performance criteria was probably due to differences in fat content of the diets.

The economic analysis of production suggests that under the current pricing structure for ingredients on the market as at June 2003 in South East Queensland, the feed cost per tonne increased as the energy level and nutrient density of the diet increased. However, feed cost per bird per day tended to be higher for the lower energy diets. This is contributed to some degree by the higher cost of unit energy (MJ) of the diets when the energy level in the diets is low, again reflected by the relative high cost of energy in lower energy ingredients compared to higher energy ingredients. Higher returns were received from bird fed medium to higher energy levels due mainly to a reduction in daily feed cost of the birds.

The experimental results of this project gives confidence to nutritionists developing minimum cost diets for laying hens. It demonstrates the ability of birds to adjust their feed intake according to the energy level of the diet when given a similar set of environmental situation. Manipulating nutrient density and energy level of the diet, in line with changes to the relative value of raw materials on the market is a major way of minimising daily feed costs. It cannot be overstressed the importance of knowing the daily feed intake of birds (or daily energy intake required) so that nutrient density and energy level can be adjusted to ensure adequate intake of critical nutrients in order to maintain bird performance and minimise nutrient surpluses. The use of controlling bulk density of the diet and its influence on economic returns needs further study.

Chapter 1

1.1 Background

Economically optimum energy levels in poultry diets depend on a number of uncontrollable factors that determine the prices paid by feed mills for cereals and cereal by-products. Recommended metabolisable energy (ME) levels for specific strains of bird may differ substantially from the levels appearing in the solutions of least cost feed (LCF) formulation runs (when ME is allowed to float). Poultry suppliers usually recommend relatively high energy levels (11.5-12.0 MJ/kg) for imported brown egg strains, but there is no evidence to support these recommendations under Australian conditions. In practice neither the breeder's recommendation nor the Least Cost Diet solution is likely to be the economic optimum. The nutritionist must make some judgment concerning (a) the effect of energy level on feed intake (which affects the levels of all other nutrients in the diet specification) and (b) the possible effect of energy level on production, whether mediated through its effect on feed intake or otherwise.

The responses of high-producing imported layers to changes in energy content of diet are not well documented. Historical information relating mainly to white leghorn strains or hybrids suggests that, within a normal range, the ME content of the diet has little effect on any performance factor other than feed intake. Because laying hens in Australia are invariably fed *ad libitum*, the relationship between dietary energy concentration and feed intake is of considerable economic importance. Early models assumed that laying hens consume only enough feed to meet their energy requirement, but it was later shown that the adjustment of feed intake to different dietary energy levels is imperfect, particularly in heavier strains of bird. The response is thus strain dependent and may also be non-linear.

It is crucially important to understand the feed intake response to changes in dietary ME concentration because:
The effective cost of a diet is not its price per tonne but the cost of the amount consumed by the flock. The predicted feed intake determines the levels of expensive nutrients that must be included in the diet to meet requirements for production. If feed intake is higher than expected nutrients will be wasted; if lower, the intake of some essential nutrients may be too low to support maximum production.

With high-producing strains of bird fed on low ME diets, energy consumption may be insufficient to sustain optimum egg output. High dietary ME levels, on the other hand, may lead to excessive energy intakes resulting in fat deposition, fatty liver syndrome, reduced egg output, increased susceptibility to heat stress and increased mortality.

The problem is exacerbated by a large number of factors such as bodyweight and strain of bird, age and condition of the flock, environmental factors, feed enzymes, feed form (pellets/mash), feed density and feed oil content and type. There is a paucity of usable information on the interactions that may occur between these factors and dietary energy level, particularly in relation to imported high producing strains of layer housed in variable temperatures and fed diets containing typically Australian ingredients such as sorghum, wheat, soybean, sunflower and meat meal. As most simple models of energy requirements include at least bodyweight, egg mass output and often environmental temperature; interactions of dietary ME level with these factors are of primary interest.

Examination of the scientific literature indicates that most of the earlier work on the relationship between energy requirement, energy intake and dietary energy level was done using diets which undoubtedly varied in bulk and fibre content as well as ME. Circumstantial evidence from a recently completed trial at the Queensland Poultry Research & Development Centre, using Isa Brown birds, suggests that the use of low energy, low density, high fibre diets was associated with greatly reduced energy intake. Although egg production was slightly depressed with this type of diet, the results indicate that the ME requirement for production is considerably lower than the typical ME intake for that strain of bird. Experimentally, it would be useful to isolate the effects of variation in AME level from the possible concomitant effects of diet density and fibre content. This appears to be feasible. Another factor that tends to vary with energy level is the oil content of the diet. Over a wide range of AME levels it is not possible to maintain a constant oil level without using artificial ingredients such as pure starch and/or artificial or unusual fillers. However, it is possible to maintain a good balance of fatty acids and to restrict the variation in fatty acids that have known effects on performance (such as linoleic acid).

Literature Review

The energy requirements of laying hens have been widely studied and reviewed. Work begun in the early 1950's (e.g. Hill and Dansky, 1954) showed that birds have a certain energy requirement under specified conditions and that feed intake is determined largely by the concentration of productive energy in the diet. There followed a period of intense research into energy/protein relationships from which the concept of a correct "calorie:protein" ratio evolved (Combs and Romoser, 1955). One of the first equations relating feed intake of layers to dietary energy level was devised by Hill (1956). Hill's work (1956 and later) showed that, over a wide range of dietary energy concentrations, the regulation of energy intake was quite precise in (what were then considerd to be) "high-producing" White Leghorns. However Morris (1968) showed that the adjustment of feed intake to maintain the same energy intake was far from perfect. Birds on high energy diets "overconsumed" energy and gained more weight than birds on lower energy diets. The ability to adjust feed intake was shown to be strain dependent: the degree of overconsumption was correlated with the "characteristic calorie intake" of the strain. Heavier strains with a high energy intake adjusted their feed intake less efficiently than lighter strains with a low energy intake. Thus Morris concluded that the widely held principle that birds adjust their feed intake to maintain a constant energy intake is not tenable and this in turn will affect the formulation of a diet designed to minimise the cost of feeding.

Leeson *et al* (1973) devised an equation relating feed intake to bodyweight, daily bodyweight gain and daily egg mass output, with corrections for varying dietary ME levels. There have been many other similar equations, including those of Byerly (1941) and Byerly *et al* (1980). The latter set of equations includes one validated with data from brown-egg Hybrids (Harco Sex links) as well as other strains:

$F = (0.534 – 0.004T)W^{0.653} + 2.76\otimes W + 0.80E$

where F = feed/bird/day (g), T = ambient temperature (^{O}C), W = bodyweight (g), $\otimes W$ = daily bodyweight change (g), E = egg mass/bird/day (g).

Gous *et al* (1987) showed that energy concentration has no effect on egg production other than via its effect on feed intake resulting in a change in the intake of the first limiting amino acid. On the other hand these authors reported that feed intake may be affected by changes in the levels of amino acids as well as by energy concentration. They concluded that amino acid requirements should not be stated either as percentages of diet or as ratios with energy.

Despite the findings of Gous *et al* (1987) there have been some recent reports (e.g. Jackson *et al*, 1999) suggesting that diets with ME levels lower than approximately 11.9 MJ/kg (2840 kcal/kg) are inadequate to support maximum production of modern White Leghorn strains during the early and middle stages of lay. In an Australian trial using Isabrown birds (Balnave and Robinson, 2000), the apparent effect of dietary ME level on feed intake was partly attributed to changes in diet density (or bulk) which occurred concomitantly with changes in ME level. Although at the lowest energy level and density the ME intake appeared to be well below what is normally considered to be the daily requirement, egg output was not significantly affected.

There appears to be little other information on dietary ME concentrations or ME requirements relevant to Isabrown and other modern brown egg layers. Harms *et al* (2000) fed diets with ME levels of 2519, 2798 and 3078 kcal/kg to four strains of bird, including Hy-line Brown. The high energy diet contained almost 6% corn oil. Hens fed the low energy diet consumed 8.5% more feed than those on the medium diet, while hens on the high energy diet consumed only 1.5% less feed, indicating that "hens are more sensitive to lowering the energy than increasing the energy in the diet". Hy-line Brown birds were surprisingly more sensitive to energy changes than Hy-line W36 or DeKalb White birds. Egg production was unaffected by energy level. Grobas *et al* (1999) fed Isabrown hens on diets varying in AME, supplementary fat and linoleic acid content. The two AME levels used were 2680 kcal/kg and 2810 kcal/kg. When supplementary fat or linoleic acid concentration was held constant, feed intake was 4.0-5.7% lower on the higher energy diet, but energy intake, egg number and egg weight were unchanged. 4% supplementary fat (with AME held constant) improved all traits except feed conversion. This shows that fat has beneficial effects that are independent of energy effects.

Chapter 2

2.1 Objectives

The aim of the research was to precisely characterise the energy intake and requirements of imported brown-egg layer strains in terms of dietary energy concentration, feed intake, egg output, body weight and body fat content.

The economic objective is to provide information enabling the formulation of diets containing the most cost effective energy levels in different circumstances.

Chapter 3

3.1 Methodology

Performance trials

Two main experiments were conducted, the first aimed mainly at measuring the effects of dietary AME level on feed intake, egg production and egg weight throughout the greater part of the laying period, the second aimed at establishing the relationships between dietary energy level, feed intake, energy intake, egg mass, bodyweight and bodyweight gain. (The required multivariate analysis is best achieved with individual bird data). Each of the two experiments used equal numbers of IsaBrown and Hyline Brown layers. The birds were reared on site in accordance with hatchery recommendations with respect to diet, lighting program and growth rate.

Experiment 1 was a nine-month trial covering hot and cool seasons. The birds were fed wheat+sorghum based diets ranging from 11 to 12.2 MJ/kg (2627-2914 kcal/kg) in 0.3 MJ/kg increments (five ME levels). Two series of diets were used: (1) with bulk and fibre increasing as ME level declines (following most previous studies in this area and reflecting practical conditions); (2) with bulk and fibre held constant at approximately 1.3 litres/kg and 40g/kg respectively (to provide results which are not confounded by possible bulk and fibre effects). Within each series, intermediate diets were prepared by blending the two extreme diets. As fat content of the diets would inevitably increase with increasing energy content, a sound balance of fatty acids were maintained and linoleic acid levels were held constant. Amino acid levels were adjusted to ensure that the daily requirement of every essential amino acid was met. There were thus 2 x 5 x 2 treatments, each represented by six 8-bird replicates (1 replicate = four two-bird cages). Measurements included environmental temperature and relative humidity at 30-minute intervals, egg production and mortality daily, egg weights fortnightly, feed intake monthly, bodyweights monthly until 30 weeks of age and three-monthly thereafter, and carcass fat measurements on a small proportion of birds at intervals of approximately three months.

Experiment 2 was a shorter term trial (approximately 15 weeks) using individually monitored birds. The same five AME levels were studied using 25 birds of each strain. Measurements were similar to those in experiment 1, but the data was used to construct a model describing the relationships between lean and fat body weight, weight gain, egg mass output, feed intake and energy intake at each AME level. Ten representative birds from each treatment were slaughtered at termination to determine body fat content.

AME studies

Ingredients for the main trials were obtained in two batches (1) before commencing Experiment 1 and (2) half way through Experiment 1 and before commencing Experiment 2. Two sets of AME studies and laboratory analyses were therefore required to determine the AMEs and chemical analyses of the principal ingredients and to verify the AMEs of diets that were used in the main experiments. For these studies six hens were used for measurements of each principal ingredient and 15 hens for measurements of the lowest and highest energy diets in each of the two series (constant or varying density). The classical four-day excreta collection method was employed. Hens of similar weight and laying at a similar rate were selected and housed in individual metabolism cages. A conventional layer diet was used for the control group and the other diets were prepared by replacing exactly one third of the non-limestone component of the control diet by the test material. These diets were fed in mash form for a seven-day period and excreta was quantitatively collected from a tray beneath each cage on each of the last four days of the bioassay period. All excreta was then rapidly frozen after collection, the four days' collections were combined. Feed intake was measured over the same 96-h period over which the excreta was collected. In the laboratory the excreta was oven dried at 70 °C, finely ground, mixed and subsampled. Gross energy of the feed and excreta was measured by combustion in an adiabatic bomb calorimeter. A modified AME calculation was used to take account of the constant limestone component of the diets. All principal feed ingredients was also analysed for fat, fibre, protein and amino acids.

Laboratory analyses

Prior to formulating the experimental diets, dry matter, protein (N x 6.25), fibre, ash, ether extract, fat and amino acids were determined on the major ingredients. Where new batches of ingredients were used, the determinations were repeated (except for tryptophan) and the diet formula was adjusted accordingly. However, sufficient quantities of cereals were obtained for the entire trial. Dry matter, ash, fibre, ether extract and nitrogen were determined by the methods of the AOAC (1992). Amino acid analyses were undertaken by ion-exchange chromatography (Waters HPLC) after hydrolysis with 6M hydrochloric acid at 110°C for 18 h under reflux conditions. Cystine and methionine were determined as cysteic acid and methionine sulphone respectively, following performic acid oxidation. Tryptophan was measured by alkaline hydrolysis on reverse phase C18 column chromatography.

Table 1. Average composition and nutrient analysis of the experimental diets.

Ingredient composition g/kg	Low energy Float Density	High energy Float Density	Low energy Fix density	High energy Fix Density
Sorghum	381.0	476.0	290.0	437.0
Wheat	150.0	75.0	300.0	70.0
Millrun	66.0	-	55.0	19.6
Rice husk	13.3	-	22.0	-
Soybean meal (49%)	103.0	198.0	149.0	139.0
Sunflower meal	150.00	41.5	44.2	111.0
Meat & bone meal (51%)	25.0	54.0	25.0	64.9
Tallow[1]	-	42.0	-	47.5
Sunflower oil[1]	7.1	13.8	9.1	13.9
Limestone[1]granular	50.0	50.0	50.0	50.0
Limestone powder	39.6	39.9	39.8	47.5
Salt[1]	1.80	1.7	2.3	1.6
Sodium bicarbonate[1]	-	-	-	0.14
Lysine mono HCl[1]	1.81	0.29	1.17	1.29
DL-methionine[1]	2.11	2.81	2.20	2.73
Threonine	0.11	-	0.15	0.24
Vitamin & mineral premixes[2]	2.0	2.0	2.0	2.0
Choline chloride	1.0	1.0	1.0	1.0
Yolk pigment	2.0	2.0	2.0	2.0
	1000.00	1000.00	1000.00	1000.00

Nutrient analysis/kg				
ME (nominal, MJ)	11.0	12.2	11.0	12.2
ME (determined, MJ)	10.32	12.17	10.78	12.23
Density (kg/litre)	0.65	0.75	0.70	0.70
Protein (g)	173.0	184.0	172.1	183.7
Fat (g)	32.9	82.7	32.3	85.8
Fibre (g)	52.5	24.0	37.0	37.0
Lysine (g)	7.7	8.30	7.7	8.30
Methionine (g)	4.55	5.21	4.57	5.21
Met + Cys (g)	6.7	7.10	6.70	7.10
Iso-leucine (g)	6.1	6.71	6.10	6.40
Threonine (g)	5.5	6.0	5.50	6.00
Tryptophan (g)	1.97	1.96	1.96	1.90
Linoleic acid (g)	9.2	16.79	14.0	17.9
Calcium (g)	37.0	39.0	37.0	39.0
Total Phosphorus (g)	6.78	5.70	6.15	7.55
Available Phosphorus (g)	3.50	4.03	3.50	4.70
Sodium (g)	1.50	1.70	1.70	1.70
Chloride (g)	1.91	2.05	2.0	2.10

[1] These ingredients were not analysed.

[2] Premixes supplied (mg/kg diet): 2.5 retinol, 0.075 cholecalciferol, 5 α-tocopherol acetate, 2 menadione sodium bisulphite, 1 thiamine, 4 riboflavin, 2 pyridoxine, 0.01 cyanocobalamin, 1 folic acid, 10 niacin, 10 calcium pantothenate, 0.03 biotin, 150 choline, 50 Mn, 50 Zn, 50 Fe, 0.6 Mo, 0.5 Co, 0.6 I, 4 Cu, 0.07 Se, 80 Banox (BHA + BHT), yolk pigment.

Metabolisable energy determinations

Apparent metabolisable energy (AME) content of the experimental diets was determined using the classical method where total collection of excreta and measurement of feed intake was measured. Birds are housed in the experimental accommodation for at least one week prior to commencement to acclimatise them to the cages and environment. During this time they are fed a standard layer diet *ad libitum*. Six birds are then fed a control diet, and for each foodstuff being evaluated six birds are fed an assay diet. The assay diets are constructed by incorporating the test ingredient into the control diet by replacing all or most of the grain component (where the test ingredient is a cereal) or replacing a portion of the grain component and all or most of the protein supplement (where the test ingredient is a protein meal). Thus test diets may comprise 60 to 80 percent inclusion of a test cereal or 25 to 40 percent inclusion of a test protein meal.

Where the material to be assayed is a complete diet, no control group is required. All diets are fed *ad libitum* for a total period of 7 days. Food intake is measured during the last 4 days by weighing the food trough and contents at the beginning and end of the period together with any food allocations during the period. Water is constantly available from two nipple waterers per cage. Excreta are quantitatively collected from a slide-out collection tray beneath each cage on each of the last 4 days of the bioassay period. Food spillage must be minimised by resting a wire mesh grid on top of the feed to prevent raking of the feed and by not overfilling feed troughs. Any spilled food must be recovered from the excreta collection tray and the floor and dried and weighed. All excreta voided over the 4 days are collected, oven dried at 70 ^{o}C, finely ground, mixed and subsampled. Gross energy of the feed and excreta were measured by combustion in an AC-350 Leco adiabatic bomb calorimeter. AME values were then calculated using the following formula after converting all data to an as fed basis:

AME = { (Feed intake x feed GE) – (Excreta output x excreta GE) } / Feed intake

Records and evaluation

Data collection commenced at 18 weeks of age. All performance records were maintained on a group basis; mortalities were recorded as they occurred, eggs were recorded on five consecutive days each week and the percentage production was calculated as 100 x number of eggs / number of hen-days in the five-day period. Feed intake and egg weights were recorded weekly for the first 16 weeks and at four-weekly intervals thereafter. At four-week intervals all eggs laid on one day were individually weighed in air and in water at 21^{O}C to obtain estimates of specific gravity. Birds were group weighed on arrival from the grower at 16 weeks of age and individually weighed at 18, 42, 54 and at termination of the trial (66 weeks). Maximum and minimum shed temperatures were recorded five days per week. At 42, 54 and 66 weeks of twelve birds from each of the ten treatments were slaughtered and autopsied and the weight of the abdominal fat pad was measured. Statistical analyses of cumulative data were done using Genstat analysis of variance programs. The economic evaluations were based on current Queensland average price information.

Chapter 4

4.1 Detailed Results

Metabolisable energy determinations

The results of the AME assays were as follows:

Energy level 1	floating density	10.32± 0.21 MJ/kg
Energy level 2	floating density	10.76± 0.22 MJ/kg
Energy level 3	floating density	11.20± 0.20 MJ/kg
Energy level 4	floating density	11.60 ± 0.29 MJ/kg
Energy level 5	floating density	12.17 ± 0.19 MJ/kg
Energy level 1	fix density	10.78± 0.26 MJ/kg
Energy level 2	fix density	11.14 ± 0.27 MJ/kg
Energy level 3	fix density	11.50± 0.26 MJ/kg
Energy level 4	fix density	11.86 ± 0.25 MJ/kg
Energy level 5	fix density	12.23± 0.25 MJ/kg

The determined AME values for the medium to high energy diets are consistent with the calculated values but the determined value for the lower energy diets are unexpectedly low for both fixed and floating densities.

4.2 Performance trials

Experiment 1 - Health and management

The experimental flock commenced lay at approximately 18 weeks of age and reached a peak rate of lay at approximately 29 weeks of age. The birds maintained excellent health throughout the trial and the general mortality rate was low.

Air temperature in the shed varied considerably during the trial. The daily average temperature ranges in the shed were approximately19-28, 15-17 and 19-24^{o}C during the early, middle and late phases of the trial respectively (Table 2).

Table 2. Average Shed Temperatures

Date	Age (wks)	Max	Min	Avg
4-Feb	30	31.4	25.4	27.6
18-Feb	32	34.8	19.2	26
4-Mar	34	33.5	19.9	25.1
18-Mar	36	31.4	17.4	23.8
1-Apr	38	30.6	16.2	23.5
15-Apr	40	26.9	16.5	21.5
29-Apr	42	30.2	15.7	21.6
13-May	44	24.1	12.8	19
27-May	46	25.1	10.1	17.2
10-Jun	48	23.7	8.8	16.8
24-Jun	50	25.4	8.8	15.8
8-Jul	52	22.1	6.4	13.4
22-Jul	54	22.1	7.7	14.2
5-Aug	56	23.1	7.5	15.2
19-Aug	58	23.4	8.3	15.9
2-Sep	60	29.1	10.4	16.4
16-Sep	62	27.6	9.8	18.6
30-Sep	64	28.7	10.9	20.2
14-Oct	66	28.7	11.1	20.4
28-Oct	68	31.4	13.7	23.1
11-Nov	70	27.2	19.5	24.2

Bird performance data

Mean performance results for the main treatments over the 42-week trial period are presented in Tables 3-6 for the four time periods 18-30, 30-42, 42-54 and 54-66 weeks of age respectively. The principal results for all treatment combinations over the trial period are in Tables 7 and 8. Main effect results are roughly divided into summer, autumn, winter and spring months and are shown in Tables 9-12 for strain, energy and density respectively.

In the first period (18-30 weeks of age or summer, Table 3) overall there was a significant strain effect in terms of laying % ($p<0.05$), egg mass, feed intake, FCR, ME intake and ME intake/egg mass ($p<0.01$). Varying dietary energy had a significant effect on feed intake, FCR, and ME intake ($p<0.01$). Density had an effect on FCR ($p<0.05$) and ME intake ($p<0.01$). In the next 12 weeks of lay (30-42 weeks of age or autumn period, Table 4), laying % and egg weigh was affected by strain ($p<0.05$) whereas level of dietary energy had an effect on feed intake and FCR (both $P<0.01$) and bulk density influenced ME intake ($p<0.01$). There was also a significant ($p<0.05$) energy by density interaction on feed intake. In the third period (42-54 weeks of age or winter period, Table 5), there were no strain differences for any of the production parameters. Dietary energy level had a significant effect on feed intake and FCR (both $p<0.01$), whereas density had significant effect on ME intake ($p<0.01$). None of the interactions were significant. In the last period (54-66 weeks of age or spring period, Table 6), there was a significant strain effect for egg mass output ($p<0.05$). Dietary energy level had significant effect on feed intake and FCR (both $p<0.01$) and bulk dendity had significant effect on ME intake ($p<0.01$). There was a significant Density by Energy interaction for feed intake ($p<0.01$) and ME intake ($p<0.05$).

Over the entire experimental period (18-66 weeks of age, Table 7), bird strain had a significant effect on egg mass ($p<0.05$), feed intake, FCR and ME intake (all $p<0.01$). Varying the dietary energy level had a significant effect on feed intake, FCR and ME intake (all $p<0.01$) and density had a significant effect only on ME intake ($p<0.01$). Density X Energy interaction was significant for feed intake and FCR (both $p<0.05$).

Strain x Energy x Density interactions

Table 3. Layer Performance 18 – 30 weeks of age.

Strain	Density	Energy (MJ/kg)	Lay %	Egg Wt(g)	Egg mass (g/d)	Feed Intake (g/d)	FCR (FI/egg mass)	ME intake (MJ/d)	ME intake/ egg mass (MJ/kg)
ISA	Float	10.5	78.26	59.54	46.65	111.30	2.421	1.15	24.99
ISA		11.0	82.84	58.35	48.28	108.62	2.253	1.17	24.24
ISA		11.5	81.45	59.45	48.35	107.70	2.258	1.21	25.29
ISA		12.0	81.97	58.30	47.82	102.90	2.174	1.19	25.22
ISA		12.5	85.08	60.05	51.06	102.51	2.008	1.25	24.43
ISA	Fix	10.5	84.83	59.30	50.24	109.32	2.421	1.18	23.55
ISA		11.0	85.69	58.03	49.70	106.73	2.253	1.19	23.94
ISA		11.5	83.14	58.86	48.91	105.46	2.258	1.21	24.83
ISA		12.0	80.34	57.85	46.43	103.92	2.174	1.23	26.61
ISA		12.5	84.47	58.60	49.45	104.35	2.008	1.28	25.82
Hyline	Float	10.5	80.32	57.43	46.14	114.63	2.185	1.18	25.69
Hyline		11.0	79.76	58.30	46.51	113.61	2.149	1.22	26.33
Hyline		11.5	76.77	58.36	44.82	110.71	2.159	1.24	27.78
Hyline		12.0	78.99	58.60	46.27	105.11	2.244	1.22	26.42
Hyline		12.5	80.63	58.63	47.28	103.68	2.111	1.26	26.76
Hyline	Fix	10.5	79.68	57.48	45.78	110.11	2.489	1.18	25.97
Hyline		11.0	80.68	58.58	47.31	108.52	2.447	1.22	25.62
Hyline		11.5	81.49	58.80	47.88	111.41	2.480	1.24	26.83
Hyline		12.0	80.85	58.31	47.14	106.27	2.278	1.22	26.76
Hyline		12.5	80.98	58.74	47.56	108.27	2.199	1.26	27.92
Statistics									
LSD (P<0.05)			7.54	1.65	4.48	5.43	0.179	0.062	2.01
Strain			*		**	**	**	**	**
Energy						**	**	**	*
Density							*	**	
Interactions									
S X E				*					
D X E						P = 0.075	*		

Table 4. Layer Performance 30 - 42 weeks of age.

Strain	Density	Energy (MJ/kg)	Lay%	Egg Wt(g)	Egg mass (g/d)	Feed Intake (g/d)	FCR (FI/egg mass)	ME intake (MJ/d)	ME intake/ egg mass (MJ/kg)
ISA	Float	10.5	85.02	63.86	54.36	115.64	2.195	1.19	22.65
ISA		11.0	88.73	65.01	57.64	126.33	2.208	1.36	23.76
ISA		11.5	89.11	64.99	57.92	119.83	2.088	1.34	23.39
ISA		12.0	93.22	64.67	60.26	115.64	1.920	1.34	22.27
ISA		12.5	92.78	65.49	60.76	110.33	1.815	1.34	22.09
ISA	Fix	10.5	92.67	64.99	60.20	120.55	2.002	1.30	21.58
ISA		11.0	94.93	63.99	60.75	122.92	2.024	1.37	22.54
ISA		11.5	94.73	64.81	61.39	121.34	1.979	1.40	22.75
ISA		12.0	89.13	64.43	57.42	116.14	2.023	1.38	24.00
ISA		12.5	92.52	64.74	59.97	113.73	1.909	1.39	23.35
Hyline	Float	10.5	94.55	62.61	59.19	118.80	2.007	1.23	20.71
Hyline		11.0	92.77	64.24	59.60	129.93	2.182	1.40	23.48
Hyline		11.5	93.68	64.86	60.76	122.73	2.020	1.37	22.63
Hyline		12.0	94.94	64.13	60.88	119.43	1.962	1.39	22.76
Hyline		12.5	93.49	64.09	59.94	107.25	1.791	1.31	21.80
Hyline	Fix	10.5	90.18	62.91	56.78	121.41	2.153	1.31	23.21
Hyline		11.0	94.61	64.69	61.20	122.94	2.010	1.37	22.39
Hyline		11.5	93.99	64.57	60.69	125.48	2.067	1.44	23.78
Hyline		12.0	94.69	63.83	60.44	118.48	1.962	1.41	23.27
Hyline		12.5	92.36	64.86	59.92	110.87	1.856	1.36	22.70
Statistics									
LSD (P<0.05)			6.23	1.85	4.36	6.62	0.190	0.075	2.08
Strain			*	*					
Energy						**	**	**	
Density								**	
Interactions									
S X E									
D X E						*			

Table 5. Layer Performance 42 - 54 weeks of age.

Strain	Density	Energy	Lay%	Egg Wt(g)	Egg mass (g/d)	Feed Intake (g/d)	FCR (FI/egg mass)	ME intake (MJ/d)	ME intake/egg mass (MJ/kg)
ISA	Float	10.5	85.87	66.94	57.60	138.69	2.452	1.46	25.85
ISA		11.0	83.40	66.45	55.42	131.84	2.392	1.45	26.36
ISA		11.5	84.21	67.21	56.59	126.38	2.258	1.45	25.99
ISA		12.0	90.85	66.90	60.79	124.00	2.041	1.49	24.49
ISA		12.5	88.48	66.94	59.27	119.45	2.026	1.49	25.28
ISA	Fix	10.5	83.73	67.31	56.32	132.08	2.369	1.50	26.81
ISA		11.0	88.92	66.09	58.70	131.13	2.234	1.54	26.24
ISA		11.5	87.62	67.04	58.73	127.09	2.187	1.55	26.60
ISA		12.0	86.25	66.81	57.64	125.21	2.185	1.58	27.48
ISA		12.5	87.76	67.01	58.87	120.94	2.070	1.57	26.93
Hyline	Float	10.5	89.39	64.36	57.52	139.76	2.431	1.47	25.63
Hyline		11.0	86.01	66.78	57.46	134.71	2.348	1.48	25.88
Hyline		11.5	88.09	67.42	59.42	131.24	2.213	1.51	25.48
Hyline		12.0	87.16	66.19	57.71	125.90	2.185	1.51	26.22
Hyline		12.5	80.45	65.88	53.22	120.62	2.317	1.51	28.91
Hyline	Fix	10.5	84.29	65.34	55.11	133.42	2.447	1.51	27.70
Hyline		11.0	89.42	67.34	60.16	133.91	2.226	1.57	26.13
Hyline		11.5	88.69	66.48	58.92	130.29	2.214	1.58	26.92
Hyline		12.0	88.52	65.92	58.36	122.73	2.108	1.54	26.52
Hyline		12.5	84.10	67.57	56.83	120.73	2.130	1.57	27.71
Statistics									
LSD (P<0.05)			8.64	2.24	6.23	6.77	0.222	0.081	2.60
Strain									
Energy						**	**		
Density								**	*
Interactions									
S X E									
D X E									

Table 6. Layer Performance 54 – 66 weeks of age.

Strain	Density	Energy (MJ/kg)	Lay%	Egg Wt(g)	Egg mass (g/d)	Feed Intake (g/d)	FCR (FI/egg mass)	ME intake (MJ/d)	ME intake/egg mass (MJ/kg)
ISA	Float	10.5	84.82	66.97	56.87	142.47	2.612	1.50	27.53
ISA		11.0	78.60	67.49	53.05	131.23	2.592	1.45	28.57
ISA		11.5	84.18	67.27	56.62	124.79	2.217	1.44	25.52
ISA		12.0	85.08	66.61	56.62	121.11	2.160	1.45	25.92
ISA		12.5	85.83	67.88	58.23	115.76	2.000	1.44	24.96
ISA	Fix	10.5	79.09	68.12	53.76	131.00	2.501	1.48	28.31
ISA		11.0	82.67	66.42	54.81	126.86	2.326	1.49	27.31
ISA		11.5	83.49	66.65	55.60	127.59	2.341	1.55	28.47
ISA		12.0	81.16	67.23	54.54	123.55	2.289	1.55	28.79
ISA		12.5	84.73	67.19	57.01	120.67	2.138	1.57	27.81
Hyline	Float	10.5	86.23	64.13	55.29	140.72	2.548	1.48	26.85
Hyline		11.0	83.33	66.03	55.05	132.65	2.416	1.46	26.63
Hyline		11.5	87.15	67.20	58.55	132.04	2.269	1.52	26.11
Hyline		12.0	85.39	66.00	56.36	122.25	2.186	1.47	26.23
Hyline		12.5	79.23	66.14	52.36	117.41	2.274	1.47	28.38
Hyline	Fix	10.5	80.50	65.93	52.97	130.78	2.509	1.48	28.40
Hyline		11.0	87.42	67.46	58.98	131.86	2.239	1.55	26.28
Hyline		11.5	85.73	66.69	57.15	129.64	2.275	1.58	27.66
Hyline		12.0	87.26	65.32	56.91	126.67	2.230	1.59	28.05
Hyline		12.5	81.23	67.62	54.90	122.31	2.237	1.59	29.10
Statistics									
LSD (P<0.05)			11.66	2.51	7.83	7.18	0.353	0.085	4.04
Strain				*					
Energy						**	**		
Density								**	*
Interactions									
S X E									
D X E						**		*	

Table 7. Layer Performance 18 – 66 weeks of age.

10	Density	Energy	Lay%	Egg Wt(g)	Egg mass (g/d)	Feed Intake (g/d)	FCR (FI/egg mass)	ME intake (MJ/d)	ME intake/egg mass (MJ/kg)
ISA	Float	10.5	83.05	64.14	53.32	123.66	2.361	1.34	23.98
ISA		11.0	84.44	64.23	54.22	122.95	2.276	1.37	24.17
ISA		11.5	85.18	64.65	55.06	118.65	2.174	1.37	24.13
ISA		12.0	88.47	64.09	56.67	114.51	2.023	1.41	26.01
ISA		12.5	88.65	64.97	57.60	111.39	1.935	1.43	25.35
ISA	Fix	10.5	86.67	64.76	56.07	121.41	2.170	1.29	24.62
ISA		11.0	89.43	63.54	56.79	120.43	2.121	1.33	24.78
ISA		11.5	88.48	64.32	56.88	118.58	2.088	1.35	24.68
ISA		12.0	84.90	63.96	54.28	115.62	2.132	1.36	24.08
ISA		12.5	88.25	64.30	56.79	113.81	2.012	1.38	23.90
Hyline	Float	10.5	88.37	62.12	54.89	126.07	2.298	1.35	25.54
Hyline		11.0	86.47	63.83	55.19	126.39	2.291	1.39	24.46
Hyline		11.5	86.90	64.40	55.96	122.61	2.192	1.38	24.49
Hyline		12.0	87.50	63.69	55.72	117.18	2.105	1.43	25.44
Hyline		12.5	85.05	63.62	54.15	111.66	2.069	1.44	26.04
Hyline	Fix	10.5	84.81	62.75	53.23	122.33	2.312	1.31	23.96
Hyline		11.0	88.	64.40	57.05	122.30	2.145	1.38	24.95
Hyline		11.5	88.32	64.0	56.57	122.95	2.174	1.39	24.88
Hyline		12.0	88.57	63.35	56.10	116.94	2.085	1.39	25.04
Hyline		12.5	85.99	64.59	55.53	114.66	2.066	1.38	25.55
Statistics									
LSD (P<0.05)			6.24	1.80	4.14	4.52	0.044	0.052	1.68
Strain				*		**	**	**	
Energy						**	**	**	
Density								**	
Interactions									
S X E									
D X E						*	*		

Bird weight and abdominal fat

Table 8 shows the effect of strain, dietary energy and bulk density on bird weight, bird weight change, abdominal fat and mortality. At 18 weeks of age Hyline birds were 30g heavier than Isa birds ($P<0.05$) and at 66 weeks Hyline birds were 120 g heavier than Isa birds ($P<0.05$).The change in body weight of Hyline birds was 595g for Hyline birds and 437g for Isa birds ($P<0.05$) and percentage abdominal fat was significantly greater in Hyline birds (6.04 cf 5.40%). Response to dietary energy was significant for bird weight at 66weeks, body weight change and % fat at 42, 54 and 66 weeks of age.

Table 8. Effect on bird weight, bird weight change, abdominal fat and mortality.

Strain	Density	Energy (MJ/kg)	B Wt (g) (18wks)	B Wt (g) (66 wks)	BWt Change (g)	Fat (%) (42 wks)	Fat (%) (54wks)	Fat (%) (66 wks)	Mortality (%)
ISA	Float	10.5	1787.52	2111.50	410.700	3.57	4.94	3.44	6.25
ISA		11.0	1766.70	2170.40	422.450	4.16	4.82	5.62	6.25
ISA		11.5	1754.20	2226.28	496.067	5.57	6.05	6.74	4.17
ISA		12.0	1784.40	2216.32	505.683	5.45	6.28	6.22	4.17
ISA		12.5	1761.48	2230.05	439.267	6.88	5.69	6.37	6.25
ISA	Fix	10.5	1731.27	2141.97	323.983	4.45	5.08	4.24	0
ISA		11.0	1722.95	2145.40	403.700	5.92	5.57	5.04	2.08
ISA		11.5	1749.00	2245.07	472.083	4.94	5.39	4.97	0
ISA		12.0	1750.03	2255.72	431.917	6.98	6.43	5.37	4.17
ISA		12.5	1790.65	2229.92	468.567	6.33	6.36	6.09	2.08
Hyline	Float	10.5	1697.95	2149.70	562.850	4.54	5.81	4.96	2.08
Hyline		11.0	1718.77	2344.43	625.783	5.79	6.78	6.86	0
Hyline		11.5	1736.48	2338.45	649.100	7.17	7.24	7.33	4.17
Hyline		12.0	1709.40	2349.50	537.883	7.26	7.47	7.48	4.17
Hyline		12.5	1725.02	2346.55	633.750	6.96	7.63	7.27	8.33
Hyline	Fix	10.5	1739.60	2302.45	451.750	5.25	5.99	6.70	8.33
Hyline		11.0	1701.07	2326.85	625.667	6.27	6.09	7.32	6.25
Hyline		11.5	1790.63	2439.73	601.967	7.44	7.72	7.23	0
Hyline		12.0	1737.53	2275.42	640.100	5.53	6.77	6.66	8.3
Hyline		12.5	1715.63	2349.38	621.533	8.44	7.06	6.90	8.3
Statistics									
LSD (P<0.05) LSD (P<0.01)			66.087	155.30	152.88	1.56	1.91	1.85	
Strain			**	**	**	**	**	**	
Energy				**	*	**	*	**	
Density			NS	NS	NS	NS	NS	NS	

Effects of strain

In the early laying period (18-30 weeks age), Isa birds performance was better in terms of laying % (p<0.05), egg mass, feed intake and feed conversion (p<0.01) than the performance of Hyline birds. During 30 – 42 weeks of age Hyline birds had better laying % (p<0.05) but lower egg weight (p<0.05). Over the whole experimental period (18 – 66 weeks age) Isa birds laid heavier eggs (p <0.05), lower feed intake (p<0.01) and the feed conversion was better although just outside 5% level of significance (P=0.056). The ME intake of Isa birds was lower than Hyline birds (p<0.01). Thus, overall the Isa birds consumed less feed to produce the same number but heavier eggs with better feed conversion than Hyline birds.

Table 9. Effects of strain on layer performance over age (18 – 66 weeks)

Age weeks	Strain	Lay %	Egg Wt (g)	Egg mass (g/d)	Feed Intake (g/d)	FCR (FI/egg mass)	ME intake (MJ/d)	ME intake/egg mass (MJ/kg)
18-30	Isa	82.81	58.83	48.70	106.29	2.20	1.205	24.89
(Summer)	Hyline	80.01	58.33	46.67	109.23	2.35	1.239	26.61
LSD P<0.05)		2.39	0.52	1.42	1.72	0.06	0.020	0.64
LSD P<0.01)				1.88	2.27		0.026	1.46
30-42	Isa	91.28	64.70	56.07	118.25	2.01	1.341	22.84
(Autumn)	Hyline	93.53	64.08	59.94	119.73	2.00	1.357	22.67
LSD(P<0.05)		1.97	0.58	1.38	2.09	0.06	0.024	0.66
42-54	Isa	85.82	66.87	57.99	127.68	2.22	1.508	26.20
(Winter)	Hyline	86.61	66.33	57.47	129.33	2.26	1.527	26.71
LSD(P<0.05)		2.73	0.71	1.97	2.14	0.07	0.026	0.82
54-66	Isa	82.96	67.18	55.71	126.50	2.32	1.493	27.32
(Spring)	Hyline	84.35	66.25	55.85	128.63	2.32	1.519	27.37
LSD(P<0.05)		3.69	0.79	2.48	2.27	0.11	0.027	1.28
18-66	Isa	86.75	64.30	55.77	118.10	2.13	1.364	24.57
(All)	Hyline	87.05	63.68	55.44	120.31	2.17	1.386	25.03
LSD(P<0.05)		1.97	0.57	1.31	1.43	0.05	0.016	0.53
LSD(P<0.01)					1.89		0.022	

Effects of dietary energy level

Level of dietary energy did not have any significant effect on laying %, egg weight and egg mass, but had a significant (p<0.01) effect on feed intake, feed efficiency and energy intake. As dietary energy increased from 10.6 to 12.2 MJ/kg, feed intake decreased from 7g/d during 18 – 30 weeks of age, 9g/d during 30 – 42 weeks of age, 16 g/d during 42 –54 weeks of age and 17g/d during 54 – 66 weeks of age. Over the whole experimental period feed intake decreased from 123 to 113 g/d as dietary energy increased from 10.6 to 12.2 MJ/kg. Feed intake by birds on lower energy diets (up to 11.4MJ/kg) were not significantly different (123 to 120g/d), however at the higher energy levels feed intake was significantly different (p<0.01), 120 g/d for birds on 11.4MJ/kg diet compared to 113g/d for birds on 12.2 MJ/kg diet. Feed efficiency also improved (p<0.01) as dietary energy levels increased from 11.0 to 12.2 MJ/kg. Energy intake by birds on low energy diets (10.6 MJ/kg) was significantly lower (P<0.01) than birds on the higher energy diets (1.325 compared to 1.408 MJ/d). Final bodyweight also increased with increasing dietary ME level, and abdominal fat pad weight (absolute or as a proportion of body weight) at termination of the trial was lower (P<0.01) for the low ME diet than for the other diets.

Table 10. Effects of energy on layer performance over age (18 – 66 weeks)

Age Weeks	Energy (MJ/kg)	Lay %	Egg Wt (g)	Egg mass (g/d)	Feed Intake (g/d)	FCR (FI/egg mass)	ME intake (MJ/d)	ME intake/ egg mass (MJ/kg)
18-30	11.0	80.77	58.44	47.20	111.34	2.38	1.174	25.05
(Summer)	11.3	82.24	58.32	47.97	109.39	2.29	1.197	25.03
	11.6	80.71	58.87	47.49	108.82	2.31	1.235	26.18
	11.9	80.54	58.27	46.92	104.55	2.24	1.226	26.25
	12.2	82.79	59.01	48.34	104.70	2.15	1.277	26.24
LSD (P<0.05)		3.77	0.82	2.24	2.73	0.09	0.031	1.01
LSD (P<0.01)					3.59	0.12	0.041	
30-42	11.0	90.61	63.60	57.63	119.10	2.09	1.257	22.04
(Autumn)	11.3	92.76	64.48	59.80	125.53	2.11	1.374	23.04
	11.6	92.88	64.81	60.19	122.35	2.04	1.389	23.14
	11.9	92.99	64.27	59.75	117.42	1.97	1.377	23.07
	12.2	92.79	64.79	60.15	110.55	1.84	1.349	22.48
LSD (P<0.05)		3.11	0.93	2.18	3.31	0.95	0.038	1.04
LSD (P<0.01)					4.38	0.13	0.050	
42-54	11.0	85.82	65.99	56.64	135.99	2.42	1.486	26.50
(Winter)	11.3	86.94	66.66	57.93	132.99	2.30	1.512	26.15
	11.6	87.15	67.04	58.41	128.75	2.22	1.524	26.25
	11.9	88.20	66.45	58.62	124.46	2.13	1.529	26.18
	12.2	85.20	66.85	57.04	120.43	2.14	1.535	27.21
LSD (P<0.05)		4.32	1.12	3.11	3.39	0.11	0.040	1.30
LSD (P<0.01)					4.48	0.15		
54-66	11.0	82.66	66.29	54.72	136.24	2.54	1.487	27.77
(Spring)	11.3	83.01	66.85	55.47	130.65	2.39	1.486	27.20
	11.6	85.14	66.95	56.98	128.52	2.28	1.521	26.94
	11.9	84.72	66.29	56.11	123.39	2.22	1.517	27.25
	12.2	82.76	67.21	55.63	119.04	2.16	1.518	27.56
LSD (P<0.05)		5.83	1.26	3.92	3.59	0.18	0.042	2.02
LSD (P<0.01)					4.75	0.23		
18-66	11.0	85.73	63.44	54.38	123.37	2.28	1.325	24.53
(All)	11.3	87.22	63.99	55.81	123.01	2.21	1.371	24.59
	11.6	87.23	64.36	56.12	120.70	2.16	1.372	24.54
	11.9	87.36	63.77	55.69	116.06	2.08	1.399	25.14
	12.2	86.99	64.37	56.02	112.88	2.02	1.408	25.21
LSD (P<0.05)		3.12	0.89	2.07	2.26	0.07	0.026	0.84
LSD (P<0.01)					2.99	0.09	0.034	

Effects of diet density

Density did not appear to have any effect on any of the measured parameters except for FCR at 18-30 weeks of age where floating density had a significant effect ($p<0.05$) (2.25 vs 2.30).

Table 11. Effects of density on layer performance over age (18 – 66 weeks)

Age Weeks	Density	Lay %	Egg Wt (g)	Egg mass (g/d)	Feed Intake (g/d)	FCR (FI/egg mass)	ME intake (MJ/d)	ME intake/egg mass (MJ/kg)
18-30	Float	82.21	58.46	48.04	107.44	2.25	1.24	25.79
(Summer)	Fixed	80.61	58.70	47.33	108.08	2.30	1.21	25.72
LSD (P<0.05) LSD (P<0.01)		2.39	0.53	1.42	1.72	0.06	0.02 0.03	0.64
30-42	Float	92.98	64.39	59.88	119.39	2.00	1.37	22.96
(Autumn)	Fixed	91.83	64.38	59.13	118.59	2.02	1.33	22.55
LSD (P<0.05) LSD (P<0.01)		1.97	0.58	1.38	2.09	0.06	0.024 0.045	0.66
42-54	Float	86.93	66.69	57.96	127.75	2.22	1.55	26.90
(Winter)	Fixed	86.39	66.51	57.50	129.26	2.27	1.48	26.01
LSD (P<0.05) LSD (P<0.01)		2.73	0.71	1.97	2.14	0.07	0.026 0.048	0.82
54-66	Float	83.33	66.86	55.66	127.09	2.31	1.54	28.02
(Spring)	Fixed	83.98	66.57	55.90	128.04	2.33	1.47	26.67
LSD (P<0.05) LSD (P<0.01)		3.69	0.79	2.48	2.27	0.11	0.027 0.050	1.28
18-66	Float	87.40	64.00	55.93	118.90	2.14	1.39	24.96
(All)	Fixed	86.41	63.97	55.28	119.51	2.17	1.36	24.64
LSD (P<0.05) LSD (P<0.01)		1.97	0.57	1.31	1.43	0.05	0.016 0.022	0.53

Experiment 2

The aim of this experiment was to construct a model describing the relationships between body weight, weight gain, egg mass output, feed intake and energy intake at each AME level.

Health and management

The birds were housed in single-bird cages in a conventional shed provided with shutters, fans and evaporative cooling (“foggers”). Cages were of wire construction and measuring 230 wide by 460 deep by 450 mm high. All birds had continuous access to feed and water. For water, each bird had access to 2 nipple drinkers located at the back of the cage. For feed, each had its own feed trough located at the front.

The factorial design experiment included the same two strains as experiment 1 (ISA Brown and Hyline Brown). Five dietary energy levels were the same as the first experiment (11.0, 11.3, 11.6, 11.9 and 12.2 MJ/kg) as was the dietary density (floating or fixed density).

Sixty IsaBrown (brown) and sixty Hyline Brown pullets were housed in single layer cages at eighteen weeks of age. Six groups of each strain were allotted to each of the ten dietary treatments in a randomised design. The diets were fed for sixteen weeks. Feed intake, egg production and sample egg weights were recorded as well as bodyweights at 18 and 44 weeks of age. Egg production data are on the basis of five days’ records per week.

Table 12. Layer Performance 1- 16 weeks on trial.

Strain	Density	Energy	Lay%	Egg Wt(g)	Egg mass (g/d)	Feed Intake (g/d)	FCR (FI/egg mass)
ISA	Float	10.5	97.34	61.05	59.40	126.65	2.16
ISA		11.0	99.52	61.94	61.64	119.07	1.93
ISA		11.5	96.46	91.67	59.52	121.88	2.07
ISA		12.0	95.37	62.35	59.52	119.68	2.03
ISA		12.5	98.29	60.06	59.16	109.28	1.87
ISA	Fix	10.5	96.45	60.84	59.07	123.90	2.14
ISA		11.0	96.30	60.05	57.86	116.63	2.03
ISA		11.5	98.27	60.46	59.47	114.58	1.95
ISA		12.0	93.46	59.02	55.38	114.26	2.07
ISA		12.5	95.89	62.48	59.84	113.80	1.94
Hyline	Float	10.5	97.65	62.24	60.77	131.98	2.17
Hyline		11.0	99.63	64.12	63.86	128.08	1.98
Hyline		11.5	94.90	64.91	61.53	124.00	2.01
Hyline		12.0	97.54	64.66	623.00	123.20	1.98
Hyline		12.5	99.14	66.02	65.45	122.20	1.84
Hyline	Fix	10.5	93.45	62.75	58.51	122.33	2.08
Hyline		11.0	99.16	65.35	64.81	131.83	2.01
Hyline		11.5	98.85	67.41	66.85	128.3	1.94
Hyline		12.0	97.11	63.88	62.02	127.78	1.98
Hyline		12.5	97.20	65.03	63.16	124.57	1.96
Statistics							
LSD (P<0.05)							
Strain				*	**	**	
Energy						*	**
Density							
Interactions							
S X E							
D X E							

Model Construction

1. Using a prediction equation fitted to Experiment 2 data

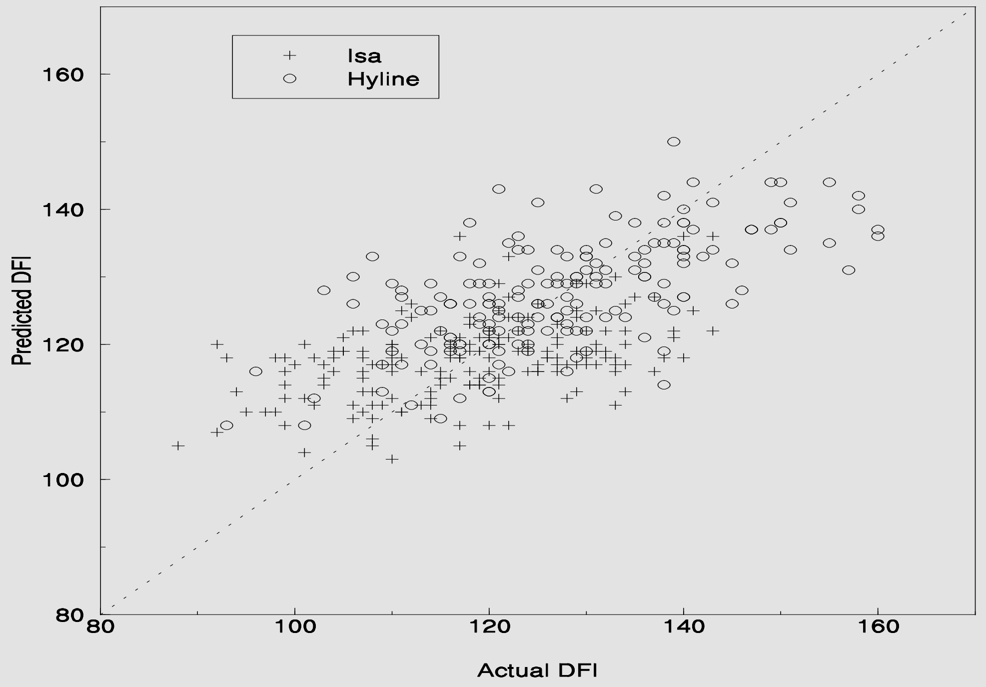
A wide range of multi-factor linear models relating feed and energy intake to dietary factors, strain and performance characteristics were considered. The best models for each strain of bird and for both strains combined often contained different components. Some of the most useful models from the point of view of predictive utility, consistently applicable structure, goodness of fit and simplicity are given below. A consistently efficient linear predictor of feed intake used a combination of dietary energy content, 18-week bodyweight, (W, kg) bodyweight gain (WC, g/d) and egg number(EN, % or egg mass EM, g).

A nonlinear regression was fitted to the data generated from experiment 2, with linearly interpolated values for the X variables bodywt change WC (periods 3, 7, 11 wks) and bodywt W (wt at end of each period)

$$PDFI= (1.015 - 0.013*T)*W^{0.640} + 0.128*WC + 0.39*EM \text{ , } 100R^2 = 41\%$$

Table 20 (in appendices) lists the PDFI = predicted DFI using the fitted model, DFI= actual DFI, along with the X data used to fit the nonlinear model (ie. EM, W, WC, T). Fig 1 is a graph of fitted vs actual DFI of experiment 2 data.

Figure 1 Fitted vs Predicted Daily Feed Intake (g/d)



2. Experiment 2 energy modelling for layers (individually caged birds), Aug-Nov 2002

Multiple linear regression equations.

Method and results

The data was sliced into 4 time periods reflecting the dates of the bird weights were taken. Regression variables were calculated with the view to predict daily feed intake from the previous period's bird weight and mean egg mass.

Dataset 1

Y= int58 = mean intake wks 5-8
X= em3 = egg mass wk 3
X= bwt4 = bird weight wk 4

Dataset 2

Y= int912 = mean intake wk 9-12
X= em57 = mean egg mass wks 5&7
X= bwt8 = bird weight wk 8

Dataset 3

Y= int1316 = mean intake wk 13-16
X= em911 = mean egg mass wks 9&11
X= bwt12 = bird weight wk 12

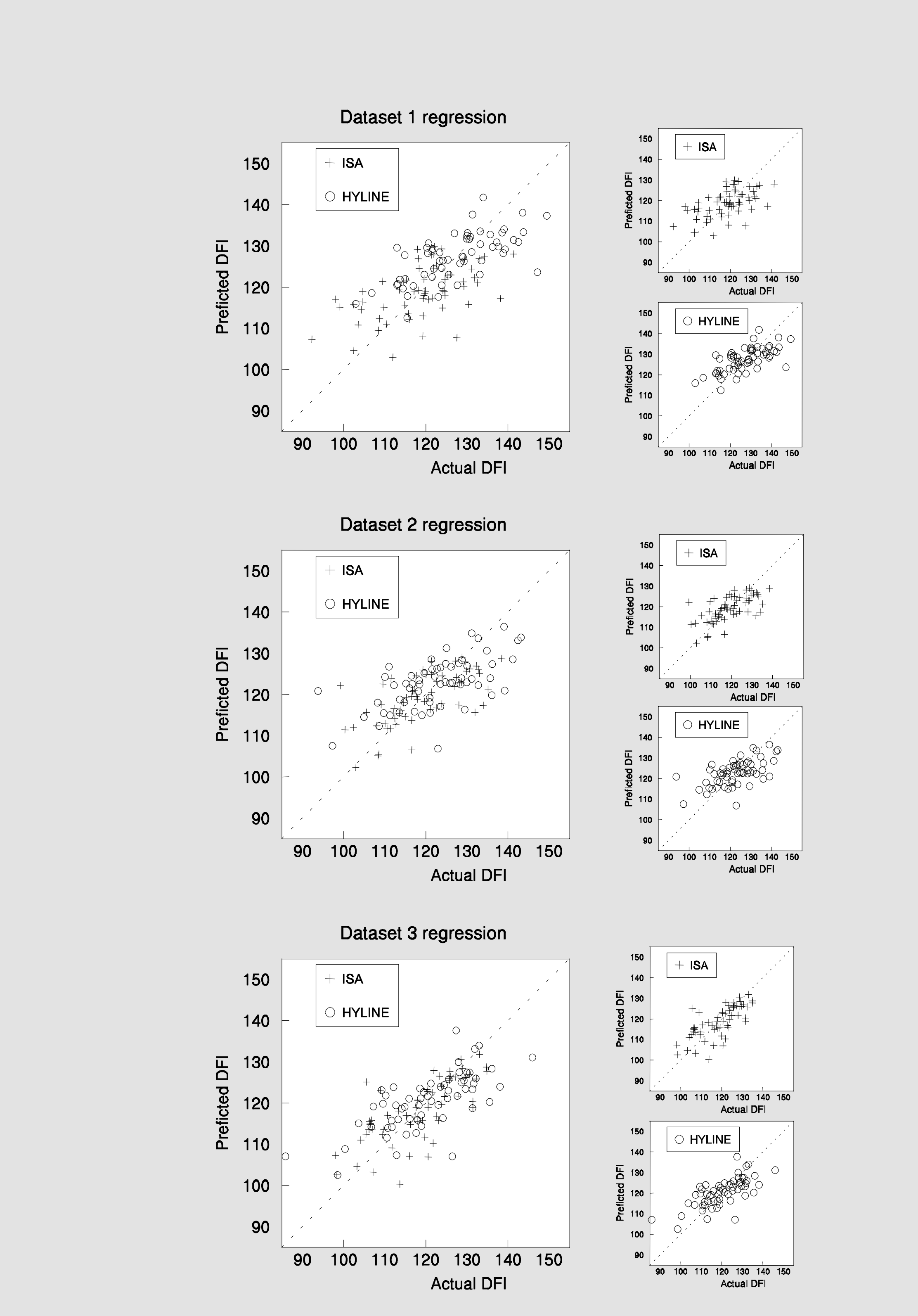
For each dataset, X variables were also fitted for bird strain (strn: X= 0/1, Isa Brown/Hy-line Brown) and treatment energy concentration (en: X= 11.0, 11.3, 11.6, 11.9, 12.2).

Dataset	Fitted equation	$100R^2$
1	int58 = 176 -2.3 strn -12.4 en + 0.046 bwt4 + 0.09 em3	46% (*P*<0.01)
2	int912 = 173 -7.1 strn -12.2 en + 0.035 bwt8 + 0.37 em57	41% (*P*<0.01)
3	int1316 = 200 -6.9 strn -14.7 en + 0.033 bwt12 + 0.40 em911	51% (*P*<0.01)

For dataset 1, bird strain and mean egg mass were not significant but have been left in for comparison.

When separate equations were fitted for strains, egg mass was significant, for Hy-Line Brown but not Isa Brown birds, for all 3 datasets. The necessary value of $100R^2$ for prediction is 32% (using the "4 times F rule", reference: *Applied Regression Analysis*, Draper & Smith 1966 p64), therefore, on this basis the models appear to have some predictive power. The graph in Fig2 shows the fitted vs observed DFI for the above three regressions equations.

Figure 2. Fitted vs Observed DFI for the three datasets



The standard errors of “b” values and partial t statistics for experiment 2 prediction equations are given in the table below. The regression partial t – statistics is used to determine the relative importance of the X variables in explaining variation in daily feed intake.

Table 13. Standard error of “b” value and partial – t statistics of prediction equations

Y var	Intercept		X var			$100R^2$
		Strain	Energy concentration	Bird wt	Egg mass	
DFI (5-8)	176	-2.3	-12.4	0.0458	0.09	46%
± SE b	22	2.3	1.9	0.0068	0.11	
|partial t|		1.0	6.5	6.7	0.8	
DFI (9-12)	173	-7.1	-12.2	0.0350	0.37	41%
± SE b	21	2.1	1.8	0.0059	0.15	
|partial t|		3.3	6.8	5.9	2.4	
DFI (13-16)	200	-6.9	-14.7	0.0332	0.40	51%
± SE b	19	1.7	1.6	0.0049	0.13	
|partial t|		4.0	8.9	6.8	3.1	

Based on the size of the partial t statistics, the relative importance of the explanatory power of the X variable energy level are 6.5, 6.8, and 8.9 for the three periods respectively. For the X variable bird weight they are 6.7, 5.9, and 6.8 respectively. For the variable strain they are 1.0, 3.3, and 4.0 respectively and for the variable egg mass they are 0.8, 2.4 and 3.1 respectively. Unit of “b” values is g/bird/d intake either lost (-ve b value) or gained (+ve b value) for each unit increase in X value. For example, a “b” value of -12.4 for X variable dietary energy concentration means a 12.4g/bird/d intake lost for each unit increase in energy dietary concentration (MJ/kg). Similarly, for X variable bird weight, “b” value of +0.0458 means intake increase of 0.0458g/bird/d for each unit increase in bird weight (g/bird).

Experiment 2 (individual bird) dataset 1 regression was developed using: Y= September DFI data and Xs = August BWT and EM. This does best for predicting Experiment 1 (groups) Autumn DFI using Xs = Summer BWT and EM. Similarly, Experiment 2 (individual bird) dataset 2 regression was developed using: Y= October DFI data and Xs = September BWT and EM. This does best for predicting Experiment 1 (groups) Winter DFI using Xs = Autumn BWT and EM. And, Experiment 2 (individual bird) dataset 3 regression was developed using: Y= November DFI data and Xs = October BWT and EM. This does best for predicting Experiment 1 (groups) Spring DFI using Xs = Winter BWT and EM.

The graphs summarising the performance of the regressions fitted from the three Experiment 2 datasets, as validated using the Experiment 1 data are given below (Figs 3 and 4). Fig 3 shows predicted daily feed intake of the group means of experiment 1 using regression equations of experiment 2 values. Fig 4 shows experiment 1 (groups) daily feed intake treatment means predicted using experiment2 (individual bird) regression equations.

Figure 3. Graph showing Experiment 1 DFI predicted using Experiment 2 regression equations

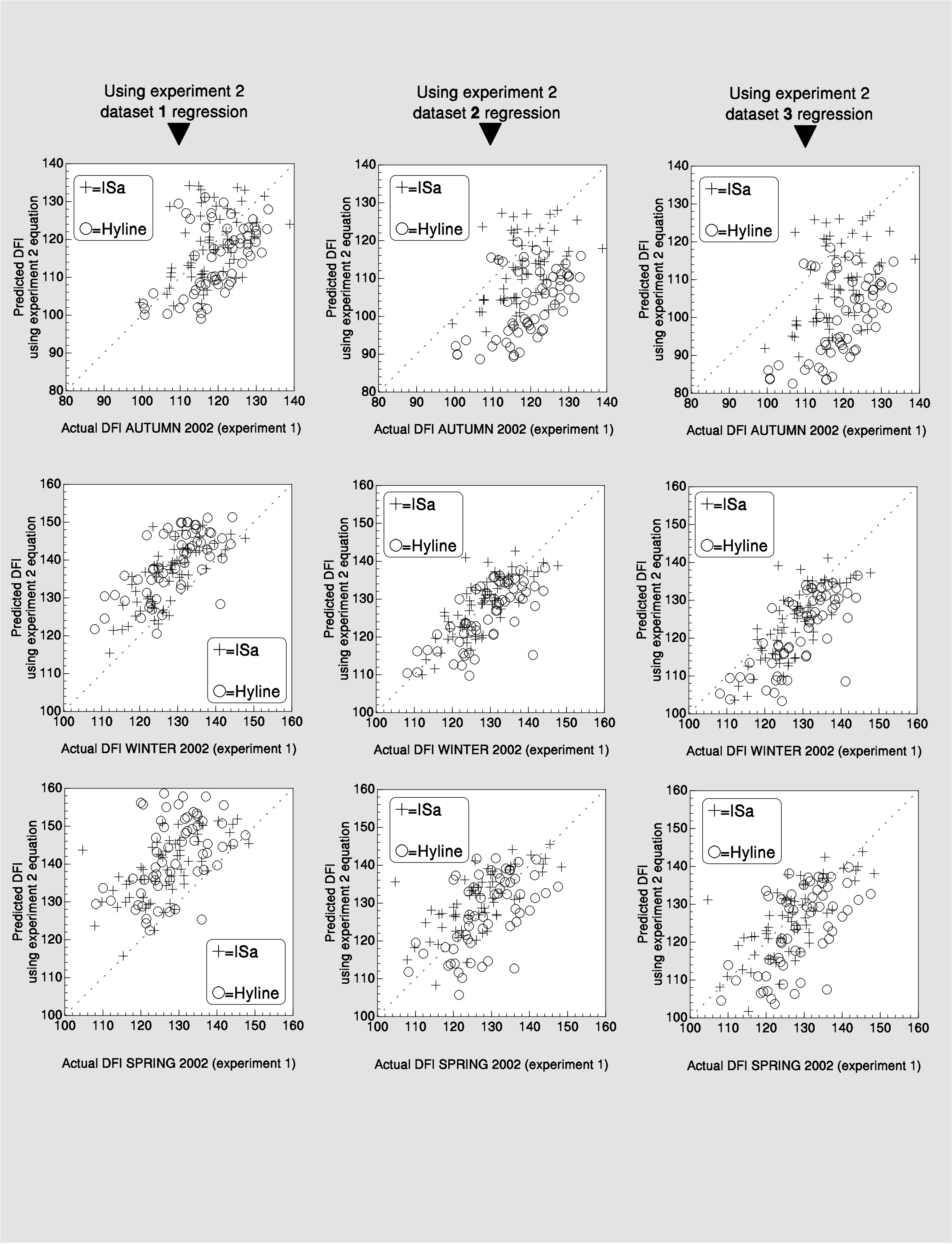
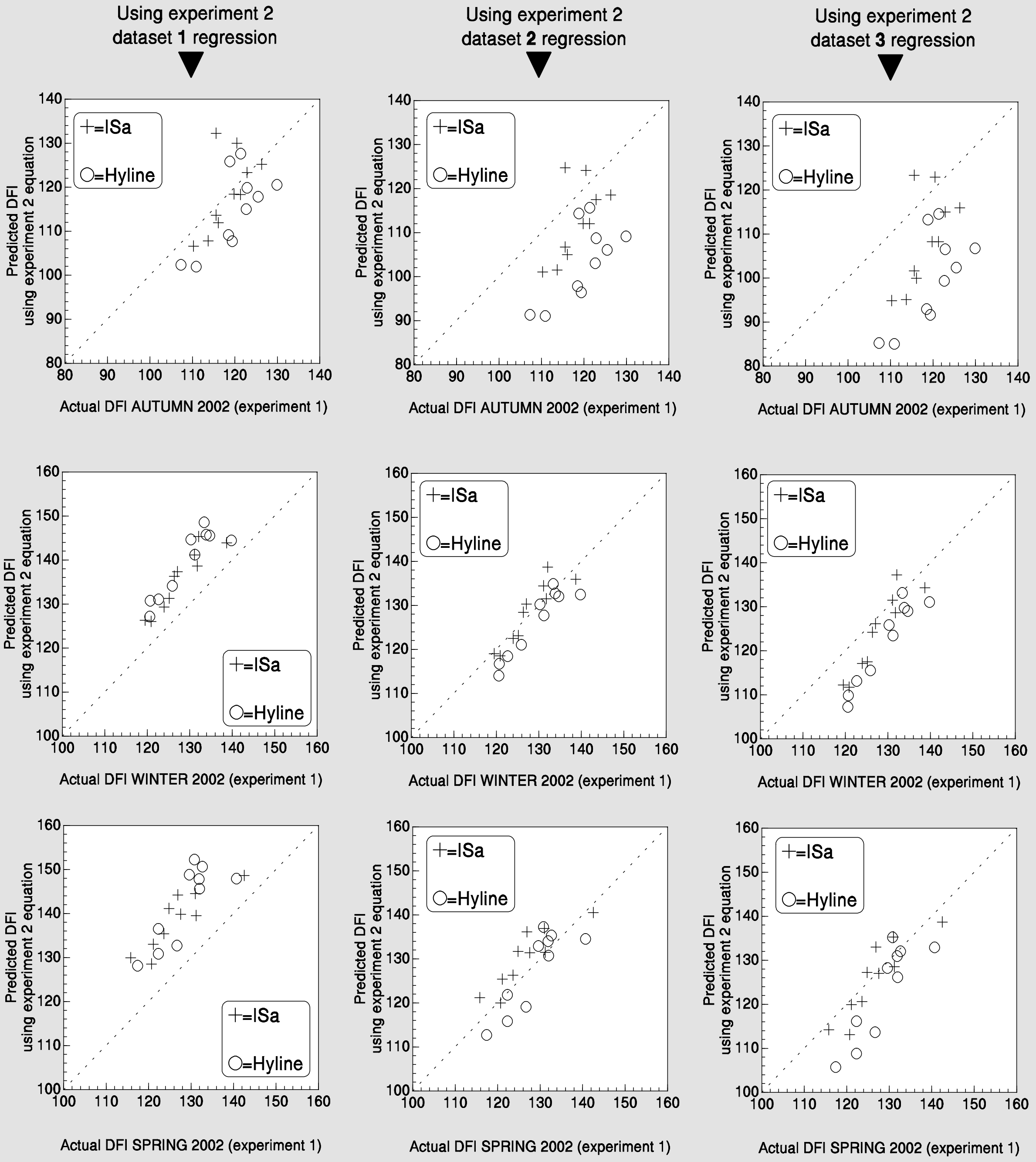


Figure 4. Graphs showing Experiment 1 DFI Treatment Means using Experiment 2 regression equations.



The difference in predicted and actual DFI could be attributed to the fact that Experiment 2 experimental unit (EU) was the individual bird while Experiment 1 EU was group, and also because Experiment 2 dataset 1 regressions had the DFI for September predicted from August BWT and EM. But for the validation data ie. Experiment 1, prediction of Autumn DFI was from Summer BWT & EM. Similarly Experiment 2 datasets 2 and 3 regressions.

Given all that, the regressions didn't do too badly. A measure of the performance of a prediction equation when applied to an independent validation dataset is the "Prediction SD" which is the average difference between predicted and actual values (it's the root mean square average difference). The prediction SDs are given in Table 14.

Table 14. Prediction SDs.

Predicting Expt 1 DFI	Using Expt 2 regression equation: Dataset1	Dataset2	Dataset3
Autumn	9.2	14.9	18.4
Winter	11.0	6.2	8.6
Spring	15.4	8.2	9.1

From the above table it can be deduced that daily feed intake for autumn can be predicted using body weight, dietary energy concentration and egg mass output from previous summer. Similarly, winter daily feed intake can be predicted from data from pervious autumn and spring feed intake predicted from data collected from previous winter.

4.3 Economic Evaluation

Assumptions

The price of feed ingredients was obtained from Applied Nutrition Pty. Ltd. and are average prices available as per early June 2003. These ingredient prices are attached.

Egg price for egg (135 cents per dozen) was sourced from an egg producer in South-East Queensland and was the average price growers receive for their eggs in early June 2003. Egg producers are paid on a per dozen basis not per kilo of egg mass, therefore the economic analysis was based on a per dozen basis. Since average egg weight in the experiment on all experimental diets was between 60g and 64g egg grade would not be an issue in the economic assessment.

A feed manufacturing cost of $60.00 per tonne was added to the raw material costs of each diet. This is a Feed Industry average manufacturing figure.

4.4 Performance Conclusions

A summary of the analyses of the experimental diets (Table 15) and estimates of daily intake of nutrients for strain calculated from the nutrient composition and feed intake (Table16, Table 17) are attached. Daily intake of amino acids of birds on all diets exceeded the minimum amount required for best performance according to their respective breeder standards. Key amino acid requirements are shown in Table 16 and Table 17 for the ISA Brown and Hyline Brown strains respectively. Nutrient (amino acid) density was clearly more than adequate for the feed intake of the birds and resulted in an excessive intake of nutrients surplus to requirements. Therefore, the absence of significant differences in egg production and egg weight between dietary treatments is expected. There was no difference in egg production between strains of birds but egg weight was different between strains. This extra egg weight for the ISA Brown strain has no economic advantage since egg producers are paid on a per dozen basis. Average egg production and egg weight over the production period would be considered as more than commercially acceptable for both strains of birds.

Daily energy intake increased as the energy level of the diet increased even though daily feed consumption decreased as the energy level of the diet increased. Clearly, the birds were not able to fully compensate to a constant energy intake as the energy level of the diet increased. This extra energy intake did not influence bird performance. The relative increase in energy intake as the energy level of the diet increased is presented in Table 16 and 17 for ISA Brown and Hyline Brown strains respectively.

4.5 Economic Evaluation

Table 18 presents a summary of the economic evaluation of birds of the experimental diets.

The relative pricing of low and high energy ingredients will influence the relative cost of diets as their energy level and nutrient densities are increased. Therefore, depending on ingredient price relativities will influence the economic evaluation of diets at a particular point in time. Under the current pricing structure for ingredients on the market as at June 2003 in South East Queensland, the feed cost per tonne increased as the energy level and nutrient density of the diet increased. However, feed cost per bird per day tended to be higher for the lower energy diets. This is contributed to some degree by the higher cost of unit energy (MJ) of the diets (Table 4) when the energy level in the diets is low, again reflected by the relative high cost of energy in lower energy ingredients compared to higher energy ingredients as at June 2003.

Under the current pricing as at June 2003 higher returns were received from bird fed medium to higher energy levels due mainly to a reduction in daily feed cost of the birds.

Fixing the bulk density of feeds had the effect of increasing the cost of feed between $2-$3 per tonne. However in this experiment, this did not adversely affect the economics, and in fact, the fixed group tended to produce more eggs and converted feed more efficiently resulting in a lower feed cost per dozen eggs. However, care should be taken on how this is interpreted since performance differences (egg production, egg weight and feed intake) between the fixed and floating bulk densities were not statistically significant. This economic difference may well be coincidental and a reflection on the size of the experiment rather than a true effect of bulk density per se. Justifying an increase of $2-$3 per tonne by fixing the bulk density needs further investigation in a larger scale experiment designed to pick up smaller differences in performance.

In practical terms, the results of this experiment confirm what has been previously known, that birds can be fed a wide range of energy levels from 10.5 MJ/kg to 12.5 MJ/kg, and provided nutrient density of the diet is adjusted to ensure adequate intake of critical or limiting nutrients, performance will be maintained. Since the birds are able to adjust their feed intake according to the energy level of the diet, the choice of energy level and nutrient density will be a function of the relative cost of feed ingredients prevailing on the market at a particular point in time. There may be a case for adjusting nutrient densities and accounting for the extra energy intake surplus to requirements which drives feed intake marginally upwards as the energy level of the diet increases (even though overall feed intake falls). Although this type of fine-tuning falls into the realm of the nutritionist to adjust depending on the environmental circumstances and the relative value of raw materials.

Table 15	ENERGY DENSITY Units	10.5 Float	11 Float	11.5 Float	12 Float	12.5 Float	10.5 Fixed	11 Fixed	11.5 Fixed	12 Fixed	12.5 Fixed
[VOLUME]		100.00	100.00	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
[DRYMAT]	%	89.262	89.372	89.481	89.591	89.700	89.424	89.531	89.638	89.745	89.853
PROTEIN	%	17.066	17.357	17.647	17.937	18.228	17.041	17.322	17.603	17.884	18.165
C_FIBRE	%	6.126	5.333	4.541	3.749	2.957	4.438	4.423	4.407	4.391	4.375
AME_A_MJ	MJ/KG	10.468	10.941	11.413	11.886	12.359	10.878	11.187	11.497	11.806	12.115
AME_A_MC	MCAL/KG	2.503	2.616	2.728	2.841	2.954	2.600	2.674	2.748	2.822	2.896
ARGININE	%	1.109	1.130	1.152	1.173	1.194	1.069	1.101	1.134	1.166	1.198
GLYCINE	%	0.889	0.925	0.961	0.998	1.034	0.871	0.929	0.988	1.047	1.105
HISTIDINE	%	0.412	0.420	0.428	0.437	0.445	0.414	0.419	0.423	0.428	0.432
LEUCINE	%	1.314	1.360	1.407	1.453	1.500	1.310	1.340	1.369	1.399	1.428
ISOLEUCINE	%	0.691	0.714	0.737	0.760	0.784	0.703	0.713	0.723	0.732	0.742
LYSINE	%	0.848	0.866	0.884	0.902	0.920	0.860	0.877	0.893	0.910	0.926
METHION	%	0.473	0.490	0.507	0.523	0.540	0.467	0.486	0.504	0.523	0.541
SERINE	%	0.747	0.770	0.794	0.817	0.841	0.778	0.784	0.789	0.795	0.801
THREONINE	%	0.601	0.615	0.629	0.643	0.657	0.605	0.613	0.622	0.630	0.639
TRYPTOPHAN	%	0.192	0.196	0.199	0.202	0.206	0.196	0.196	0.196	0.197	0.197
M+C	%	0.759	0.774	0.790	0.805	0.821	0.759	0.774	0.790	0.806	0.821
CALCIUM	%	3.821	3.882	3.943	4.004	4.065	3.835	3.892	3.949	4.006	4.063
PHOSPHOR	%	0.630	0.622	0.614	0.605	0.597	0.586	0.612	0.638	0.663	0.689
AV_PHOS	%	0.286	0.287	0.288	0.289	0.291	0.305	0.315	0.325	0.335	0.344
#CAL/PHO	%	6.062	6.241	6.425	6.614	6.809	6.545	6.362	6.193	6.038	5.894
SODIUM	%	0.119	0.123	0.126	0.130	0.134	0.138	0.138	0.137	0.137	0.136
POTASSIUM	%	0.677	0.684	0.690	0.697	0.703	0.662	0.667	0.671	0.676	0.681
CHLORIDE	%	0.248	0.241	0.235	0.228	0.222	0.254	0.253	0.251	0.250	0.248
FAT	%	3.111	4.325	5.539	6.753	7.967	3.099	4.495	5.891	7.287	8.682
C18:2W6LIN	%	1.413	1.502	1.591	1.680	1.769	1.394	1.513	1.632	1.752	1.871

Table 16. ISA Brown Daily Nutrient Intake

ENERGY DENSITY	10.5 Float	11 Float	11.5 Float	12 Float	12.5 Float	10.5 Fixed	11 Fixed	11.5 Fixed	12 Fixed	12.5 Fixed	Mean
Feed Intake	123.66	122.95	118.65	114.51	111.39	121.41	120.43	118.58	115.62	113.81	118.10
[DRYMAT]	110.38	109.88	106.17	102.59	99.92	108.57	107.82	106.29	103.76	102.26	105.77
PROTEIN	21.10	21.34	20.94	20.54	20.30	20.69	20.86	20.87	20.68	20.67	20.80
C_FIBRE	7.57	6.56	5.39	4.29	3.29	5.39	5.33	5.23	5.08	4.98	5.31
AME_A_MJ	1.29	1.35	1.35	1.36	1.38	1.32	1.35	1.36	1.37	1.38	1.35
AME_A_MC	0.31	0.32	0.32	0.33	0.33	0.32	0.32	0.33	0.33	0.33	0.32
ARGININE	1371.47	1389.74	1366.36	1343.02	1330.11	1298.36	1326.52	1344.20	1347.75	1363.17	1348.07
GLYCINE	1099.41	1137.61	1140.78	1142.43	1151.63	1057.32	1119.38	1171.69	1210.21	1257.97	1148.84
HISTIDINE	509.98	516.95	508.41	499.89	495.23	502.59	504.08	501.79	494.59	492.09	502.56
LEUCINE	1624.71	1672.47	1669.06	1663.99	1670.37	1590.43	1613.25	1623.59	1617.29	1625.68	1637.08
ISOLEUCINE	854.30	877.90	874.71	870.74	872.84	854.02	858.62	856.75	846.40	844.01	861.03
LYSINE	1048.40	1064.45	1048.53	1032.50	1024.37	1044.15	1055.67	1059.09	1051.80	1054.19	1048.32
METHION	585.08	602.27	601.03	599.19	601.47	567.34	584.98	597.88	604.29	615.82	595.93
SERINE	923.73	947.22	941.87	935.82	936.41	944.27	943.69	936.12	919.51	911.77	934.04
THREONINE	743.20	756.28	746.58	736.69	732.33	734.17	738.51	737.28	728.74	727.04	738.08
TRYPTOPHAN	237.87	240.57	236.08	231.63	229.01	237.38	235.87	232.65	227.23	224.06	233.24
M+C	938.11	951.86	937.04	922.17	914.38	921.34	932.66	936.81	931.44	934.59	932.04
CALCIUM	4.72	4.77	4.68	4.59	4.53	4.66	4.69	4.68	4.63	4.62	4.66
PHOSPHOR	0.78	0.76	0.73	0.69	0.67	0.71	0.74	0.76	0.77	0.78	0.74
AV_PHOS	0.35	0.35	0.34	0.33	0.32	0.37	0.38	0.39	0.39	0.39	0.36
#CAL/PHO	6.06	6.24	6.43	6.61	6.81	6.54	6.36	6.19	6.04	5.89	6.30
SODIUM	0.15	0.15	0.15	0.15	0.15	0.17	0.17	0.16	0.16	0.16	0.16
POTASSIUM	0.84	0.84	0.82	0.80	0.78	0.80	0.80	0.80	0.78	0.78	0.80
CHLORIDE	0.31	0.30	0.28	0.26	0.25	0.31	0.30	0.30	0.29	0.28	0.29
FAT	3.85	5.32	6.57	7.73	8.87	3.76	5.41	6.99	8.42	9.88	6.68
C18:2W6LIN	1.75	1.85	1.89	1.92	1.97	1.69	1.82	1.94	2.03	2.13	1.90
Relative Increase in AME Intake %	0.000	3.917	4.616	5.148	6.352	0.000	2.014	3.225	3.357	4.405	

Table 17. Hy-Line Brown Daily Nutrient Intake

ENERGY DENSITY	10.5 Float	11 Float	11.5 Float	12 Float	12.5 Float	10.5 Fixed	11 Fixed	11.5 Fixed	12 Fixed	12.5 Fixed	Mean
Feed Intake	126.07	126.39	122.61	117.18	111.66	122.33	122.30	122.95	116.94	114.66	120.31
[DRYMAT]	112.53	112.96	109.71	104.98	100.16	109.39	109.50	110.21	104.95	103.03	107.74
PROTEIN	21.52	21.94	21.64	21.02	20.35	20.85	21.18	21.64	20.91	20.83	21.19
C_FIBRE	7.72	6.74	5.57	4.39	3.30	5.43	5.41	5.42	5.14	5.02	5.41
AME_A_MJ	1.32	1.38	1.40	1.39	1.38	1.33	1.37	1.41	1.38	1.39	1.38
AME_A_MC	0.32	0.33	0.33	0.33	0.33	0.32	0.33	0.34	0.33	0.33	0.33
ARGININE	1398.20	1428.62	1411.96	1374.34	1333.34	1308.19	1347.12	1393.74	1363.14	1373.36	1373.20
GLYCINE	1120.83	1169.44	1178.85	1169.07	1154.42	1065.33	1136.76	1214.87	1224.03	1267.37	1170.10
HISTIDINE	519.92	531.41	525.38	511.54	496.43	506.39	511.90	520.29	500.24	495.77	511.93
LEUCINE	1656.38	1719.26	1724.77	1702.79	1674.42	1602.48	1638.30	1683.42	1635.76	1637.82	1667.54
ISOLEUCINE	870.95	902.46	903.90	891.04	874.96	860.49	871.96	888.33	856.07	850.32	877.05
LYSINE	1068.83	1094.24	1083.52	1056.58	1026.85	1052.06	1072.06	1098.12	1063.81	1062.06	1067.81
METHION	596.49	619.12	621.08	613.16	602.93	571.64	594.07	619.91	611.18	620.42	607.00
SERINE	941.73	973.72	973.31	957.65	938.68	951.43	958.34	970.62	930.01	918.58	951.41
THREONINE	757.68	777.44	771.49	753.86	734.11	739.73	749.98	764.45	737.06	732.47	751.83
TRYPTOPHAN	242.50	247.30	243.96	237.04	229.56	239.18	239.53	241.22	229.83	225.73	237.59
M+C	956.39	978.49	968.31	943.67	916.59	928.32	947.15	971.34	942.08	941.57	949.39
CALCIUM	4.82	4.91	4.83	4.69	4.54	4.69	4.76	4.86	4.68	4.66	4.74
PHOSPHOR	0.79	0.79	0.75	0.71	0.67	0.72	0.75	0.78	0.78	0.79	0.75
AV_PHOS	0.36	0.36	0.35	0.34	0.32	0.37	0.39	0.40	0.39	0.39	0.37
#CAL/PHO	6.06	6.24	6.43	6.61	6.81	6.54	6.36	6.19	6.04	5.89	6.30
SODIUM	0.15	0.15	0.16	0.15	0.15	0.17	0.17	0.17	0.16	0.16	0.16
POTASSIUM	0.85	0.86	0.85	0.82	0.79	0.81	0.82	0.83	0.79	0.78	0.82
CHLORIDE	0.31	0.31	0.29	0.27	0.25	0.31	0.31	0.31	0.29	0.28	0.29
FAT	3.92	5.47	6.79	7.91	8.90	3.79	5.50	7.24	8.52	9.96	6.80
C18:2W6LIN	1.78	1.90	1.95	1.97	1.98	1.70	1.85	2.01	2.05	2.15	1.93
Relative Increase in AME Intake %	0.00	4.78	6.04	5.54	4.57	0.00	2.82	6.22	3.75	4.39	

Table 18. Economic Analysis of Experimental Diets

ENERGY DENSITY PRODUCTION PARAMETERS			10.5 Float	11 Float	11.5 Float	12 Float	12.5 Float	10.5 Fixed	11 Fixed	11.5 Fixed	12 Fixed	12.5 Fixed	Mean
PRICE OF FEED ($/TONNE)			357.338	366.48	375.621	384.763	393.905	360.569	368.213	375.856	383.5	391.144	
PRICE OF FEED ($/TONNE) + Mix Cost		60	417.338	426.48	435.621	444.763	453.905	420.569	428.213	435.856	443.5	451.144	
PRICE OF EGGS (CENTS/DOZEN)		135											
PRICE OF EGGS (CENTS/KG)		187.50											
AVERAGE EGG WEIGHT (g)		60											
ISA BROWN	DAILY FEED INTAKE (g/bird/)		123.7	123.0	118.7	114.5	111.4	121.4	120.4	118.6	115.6	113.8	118.1
	EGG PRODUCTION		83.05	84.44	85.18	88.47	88.65	86.67	89.43	88.48	84.9	88.25	86.8
	EGG WEIGHT		64.14	64.23	64.65	64.09	64.97	64.76	63.54	64.32	63.96	64.3	64.3
	EGG MASS		53.27	54.24	55.07	56.70	57.60	56.13	56.82	56.91	54.30	56.74	55.8
	FEED COST/BIRD (Cents/day)		5.16	5.24	5.17	5.09	5.06	5.11	5.16	5.17	5.13	5.13	5.14
	FCR (KgFeed/Dozen Eggs)		1.79	1.75	1.67	1.55	1.51	1.68	1.62	1.61	1.63	1.55	1.64
	FEED COST/Dozen Egg (Cents)		74.57	74.52	72.81	69.08	68.44	70.70	69.20	70.10	72.48	69.82	71.2
	MARGIN/Dozen Eggs (Cents)		60.43	60.48	62.19	65.92	66.56	64.30	65.80	64.90	62.52	65.18	63.83
	COST/MJ AME (Cents/MJ)		3.99	3.90	3.82	3.74	3.67	3.87	3.83	3.79	3.76	3.72	3.81
HYLINE BROWN	DAILY FEED INTAKE (g/bird)		126.1	126.4	122.6	117.2	111.7	122.3	122.3	123.0	116.9	114.7	120.3
	EGG PRODUCTION		88.37	86.47	86.9	87.5	85.05	84.81	88.56	88.32	88.57	85.99	87.1
	EGG WEIGHT		62.12	63.83	64.4	63.69	63.62	62.75	64.4	64.07	63.35	64.59	63.7
	EGG MASS		54.90	55.19	55.96	55.73	54.11	53.22	57.03	56.59	56.11	55.54	55.4
	FEED COST/BIRD (Cents/day)		5.26	5.39	5.34	5.21	5.07	5.14	5.24	5.36	5.19	5.17	5.24
	FCR (KgFeed/Dozen Eggs)		1.71	1.75	1.69	1.61	1.58	1.73	1.66	1.67	1.58	1.60	1.66
	FEED COST/Dozen Egg		71.45	74.80	73.76	71.48	71.51	72.80	70.96	72.81	70.27	72.19	72.2

	(Cents)											
	MARGIN/Dozen Eggs (Cents)	63.55	60.20	61.24	63.52	63.49	62.20	64.04	62.19	64.73	62.81	62.80
	COST/MJ AME (Cents/MJ)	3.99	3.90	3.82	3.74	3.67	3.87	3.83	3.79	3.76	3.72	3.81
FLOAT versus FIXED BULK DENSITIES												
FLOAT	FEED INTAKE	119.51										
	EGG PRODUCTION	86.41										
	EGG WEIGHT	63.97										
	EGG MASS	55.28										
	FCR (KgFeed/Dozen Eggs)	1.66										
	FEED COST/Dozen Egg (Cents)	72.24										
	MARGIN/Dozen Eggs (Cents)	62.76										
FIXED	FEED INTAKE	118.90										
	EGG PRODUCTION	87.40										
	EGG WEIGHT	64.00										
	EGG MASS	55.94										
	FCR (KgFeed/Dozen Eggs)	1.63										
	FEED COST/Dozen Egg (Cents)	71.13										
	MARGIN/Dozen Eggs (Cents)	63.87										

Chapter 5

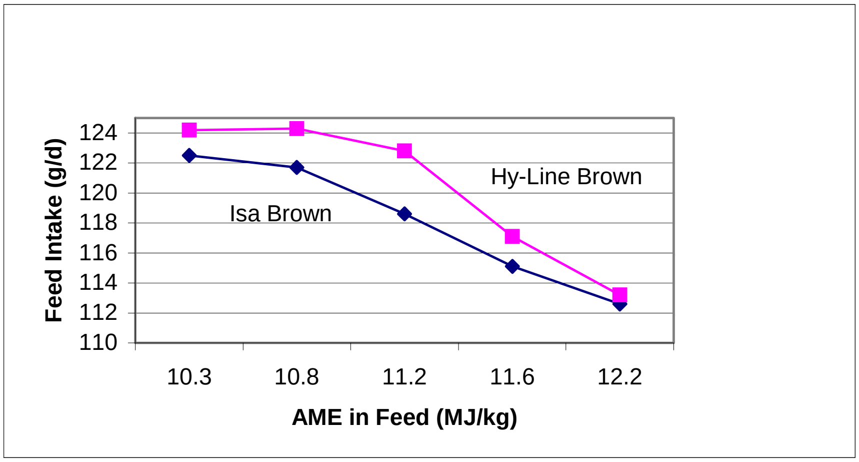
5.1 Discussion of results

The determined and nominal AME value of the high energy diets were in close agreement, however the determined values for the low energy diets were considerably lower than the calculated values. It could be that ingredient used to formulate low energy diets (rice husk) could contains factors that interferes with utilisation of energy from the other ingredients. This is in agreement with findings from Belnave and Robinson (2000) who also used rice husk to lower the energy content of the diet.

Previous trials at this research centre indicate that the characteristic ME intake of Isabrown hens in Queensland is within the range 1.35-1.4 MJ/day. At each stage of the trial this intake was generally met by the medium energy diet, exceeded by the high energy diet but never attained by the low energy diet. These differences in energy intake may account for the small but sometimes significant differences in egg weight, egg mass output, body weight gain and abdominal fat body weight between the three treatments. It is perhaps surprising that the reduced ME intake on the low energy diet did not have a more adverse effect on performance. Despite their somewhat lower egg mass output, birds on the low ME diet converted energy and protein to egg mass more efficiently than those on the high ME diet.

The results indicate that dietary energy content, but not density, is an important determinant of feed and energy intake. However, it appears that the response is neither linear nor the same for the two strains of bird (Fig.5). It appears that both strain over consumes energy at dietary ME levels above 11.2 MJ/kg and under consumes energy at dietary ME levels below 10.8 MJ/kg. The "typical" ME intake of these strains appears to be about 1400 kJ/d (335 kcal/d) for the brown strain. These intakes were more or less met by diets with MEs in the range 11.6-12.2 and 10.8 – 12.2 MJ/kg respectively for Isa and Hy-Line Brown birds. The energy intake of the two strain are in close agreement with the figure of 1370-1380 kJ/d interpolated from data of Harms *et al* (2000) for Hy-line Brown and Grobas *et al* (1999) for Isabrown birds and a value of 1403 kJ/d recorded by Balnave and Robinson (2000) for Isabrown birds on a diet containing 11.4 MJ/kg.

Figure 5. Feed Intake of Isa Brown and Hy-Line Brown



Egg mass output appears not to be affected by increase in dietary energy but feed conversion efficiency improved with increase in dietary energy. This was for both bird strains. The diets with the highest ME level (12.2MJ/kg) were the most efficient in terms of feed-to-egg mass. In both strains, the lower egg mass output at the lowest ME level (10.3

MJ/kg) resulted in poorer feed conversion than with diets of higher ME, but energy conversion was similar to diets containing 11.6 or 12.2MJ/kg ME. In these strains energy conversion was optimised with diets containing11.2 MJ/kg.

The feed intake/dietary ME plots of both strains together are consistent with an S-shaped model which assumes that each strain of bird has a characteristic range of dietary ME levels over which energy intake is relatively constant, while outside this range energy is under- or over consumed. This model is consistent with the data of Harms *et al* (2000), which show that feed intake of Isa Brown hens decreases by only 1.5% when ME intake increases from 11.7 MJ/kg to 12.9 MJ/kg (compared with an 8.5% increase between 11.7 and 10.5 MJ/kg), resulting in considerable over consumption of energy. It would be convenient to suppose that the characteristic ME range (over which energy intake remains relatively stable) is related to the typical bodyweight of the strain, but data from other sources suggest this may not be the case. The pattern of energy intake found by Robinson (2001) for Hy-line Brown is much higher (131 – 122 g/d intake on diets ranging from 10.5 – 11.8 MJ/kg) than the in the present study (124 –113 g/d intake on diets ranging from 10.5 – 12.5 MJ determined ME). Increasing ME in the diet did not necessarily lea to improvement in egg mass production but rather it was used for fat deposition and subsequent bird weight gain over the experimental period.

In constructing a prediction model, dietary energy level, bird body weight, strain of bird and egg mass (in order of importance) were best linear independent predictor of feed intake compared to diet density and other performance characteristics. It was possible to predict with reasonable accuracy the feed intake of the two strains using data obtained from previous months bird body weight, egg mass output and the energy level of the diets.

The economics of feeding IsaBrown and Hy-line Brown hens on diets ranging in ME content from 11 to 12.3 MJ AME/kg, is shown in Table 19. The cost of the diet per kg is relatively flat at energy levels below 11.3 MJ AME/kg, based on the prices paid for the ingredients used in the experiment. However price/kg rises as AME content increases from 11.6 MJ/kg upwards. Minimum energy cost is at the higher dietary energy level, mainly because of the lower intake of high energy diets The feeding cost per bird per day is lowest at the highest energy level and so is the cost per dozen eggs. With eggs priced at $1.35/dozen, the margin over feed cost per dozen eggs is 3.5 cents for Isa Brown hens on 12.2 MJ/kg dietary energy and 1.25cents for Hy-line Brown hens fed diets with an energy level of 11.9MJ/kg. Thus it is profitable to high energy diets to modern brown egg layers.

Table 19. Current economics of feeding ISA Brown and Hy-Line Brown layers diets with different ME levels

ISA Brown

Diet ME[1] (MJ/kg)	Feed intake (g/d)	Diet cost (c/kg)	Feeding cost (c/d)	Energy cost (c/MJ AME)	Feed cost/dz eggs ©	Margin (c/dz eggs)
10.5	122.6	42.0	5.14	3.93	72.635	62.365
11.0	121.7	42.7	5.2	3.87	71.86	63.14
11.5	118.7	43.6	5.17	3.81	71.455	63.545
12.0	115.1	44.4	5.11	3.75	70.78	64.22
12.5	112.6	45.2	5.09	3.70	69.13	65.87

[1] Major nutrients are included at concentrations proportional to ME level.

Hy-line Brown

Diet ME[1] (MJ/kg)	Feed intake (g/d)	Diet cost (c/kg)	Feeding cost (c/d)	Energy cost (c/MJ AME)	Feed cost/dz eggs ©	Margin (c/dz eggs)
10.5	124.2	42.0	5.2	3.93	72.125	62.875
11.0	124.35	42.7	5.32	3.87	72.88	62.12
11.5	122.8	43.6	5.35	3.81	73.285	61.715
12.0	117.05	44.4	5.2	3.75	70.875	64.125
12.5	113.2	45.2	5.12	3.70	71.85	63.15

Chapter 6

6.1 Conclusion

Isabrown and Hy-line Brown strains were both efficient at adjusting feed intake to maintain energy intake when fed diets varying in ME content and either floating or fixed density over a limited range. Daily energy intake increased as the energy level of the diet increased even though daily feed consumption decreased as the energy level of the diet increased. Clearly, the birds were not able to fully compensate to a constant energy intake as the energy level of the diet increased. This extra energy intake did not influence bird performance. Both strains “over consumed” energy when given diets containing 11.2 MJ/kg. A reasonable interpretation of the results is that changes in feed intake were mainly attributable to dietary ME level while diet density had little influence on feed intake. The apparent effect of density on other performance criteria was probably due to differences in fat content of the diets. Current breeder recommendation for dietary energy for Isa Brown bird of11.6-11.8MJ and of Hy-line Brown bird 11.2-11.9 appear to be satisfactory under Queensland conditions.

Results from this experiment gives confidence to nutritionists developing minimum cost diets for laying hens. It demonstrates the ability of the bird to adjust her feed consumption according to the energy level of the diet when given a similar set of environmental circumstances. Manipulating nutrient density and energy level of the diet, in line with changes to the relative value of raw materials on the market is a major way of minimising daily feed costs. It cannot be overstressed the importance of knowing the daily feed consumption of birds (or daily energy consumption required) so that nutrient density and energy level can be adjusted to ensure adequate intake of critical nutrients in order to maintain bird performance and minimise nutrient surpluses.

6.2 Implications

The outcomes of this work are relevant mainly to poultry nutritionists, least cost diet formulators and egg producers. Bird performance characteristics, bird body weight and dietary energy concentration from the previous month can be satisfactorily be used to determine the daily feed intake of the birds and thus adjust dietary specifications for maximum economic gain. Although breeders of high performance brown egg layers recommend diets with a medium to high energy content and high protein content, the results of this study suggest that diets with a low to medium energy content can be used without any detrimental effect on performance provided the amino acid concentration in the diet is adequate. The use of controlling bulk density of the diet and its influence on economic returns needs further study.

6.3 Communications strategy

Some of the main results from this project have so far been presented and published only as conference proceedings and minor articles. Scientific papers will follow.

Energy requirements of Isa Brown and Hy-line Brown layers. Proceedings of the Australian Poultry Science Symposium. Vol 16, 2004. D.N. Singh, P.C. Trappett, T. Nagle and K.M. Barram.

Energy requirements of imported brown-egg layers. Queensland Poultry Science Symposium. Research - how is it working for you? Proceedings. Vol 11, 2003. D. Singh, P.C. Trappett, T. Nagle and K.M. Barram.

Appendices

Table 20. Predicted Daily Feed Intake

Wk	Str	Diet	Cage	DFI	PDFI	EM	W	WC	T
3	1	1	12	125	116	53.9	1760	-13.5	15.2
3	1	2	14	110	120	62.5	1760	-13.5	15.2
3	1	3	8	141	125	41.1	1971	40.4	15.2
3	1	4	19	105	119	39.8	1890	13.5	15.2
3	1	5	17	118	123	70.6	1760	-13.5	15.2
3	1	6	9	130	122	55.4	1850	0	15.2
3	1	7	15	106	111	57.1	1679	-40.4	15.2
3	1	8	13	120	122	57.3	1850	0	15.2
3	1	9	2	133	117	35	1890	13.5	15.2
3	1	10	20	130	129	57.5	1931	26.9	15.2
3	2	1	11	129	126	64.7	1969	-26.9	15.2
3	2	2	7	136	134	65.8	2040	13.5	15.2
3	2	3	4	139	135	64.5	2090	13.5	15.2
3	2	4	16	140	134	58.8	2081	26.9	15.2
3	2	5	3	130	133	63.9	2040	13.5	15.2
3	2	6	5	150	138	68.3	2140	13.5	15.2
3	2	7	6	120	127	63.6	1960	-13.5	15.2
3	2	8	10	160	137	57.7	2121	40.4	15.2
3	2	9	1	132	129	60.9	2000	0	15.2
3	2	10	18	133	139	66.8	2131	26.9	15.2
3	1	1	38	132	118	42.7	1840	13.5	15.2
3	1	2	27	122	127	57	1881	26.9	15.2
3	1	3	33	124	124	57.8	1840	13.5	15.2
3	1	4	34	117	118	49.1	1800	0	15.2
3	1	5	26	112	124	58.7	1840	13.5	15.2
3	1	6	25	125	126	63.4	1840	13.5	15.2
3	1	7	40	121	120	54.2	1800	0	15.2
3	1	8	37	92	120	54.2	1800	0	15.2
3	1	9	21	101	120	55.9	1800	0	15.2
3	1	10	22	115	116	53.5	1760	-13.5	15.2
3	2	1	30	160	136	71.1	2040	13.5	15.2
3	2	2	28	147	137	69.6	2031	26.9	15.2
3	2	3	39	158	142	66	2112	53.8	15.2
3	2	4	35	149	144	72.6	2112	53.8	15.2
3	2	5	31	122	135	65.5	2031	26.9	15.2
3	2	6	36	127	124	59.7	1910	-13.5	15.2
3	2	7	29	151	141	68.8	2121	40.4	15.2
3	2	8	23	129	130	51.8	2031	26.9	15.2
3	2	9	24	155	144	71.6	2112	53.8	15.2
3	2	10	32	121	143	64.9	2162	53.8	15.2
3	1	1	49	118	124	57.8	1840	13.5	15.2
3	1	2	59	127	121	53.4	1790	13.5	15.2
3	1	3	54	122	133	62.3	1912	53.8	15.2
3	1	4	47	106	122	37.5	1921	40.4	15.2
3	1	5	41	140	136	48.8	2042	80.8	15.2
3	1	6	45	134	120	54.6	1800	0	15.2
3	1	7	58	108	117	59.6	1710	-13.5	15.2
3	1	8	50	102	118	54.4	1750	0	15.2
3	1	9	60	127	120	47.1	1840	13.5	15.2
3	1	10	53	125	117	59.2	1710	-13.5	15.2
3	2	1	44	145	126	56.3	1950	0	15.2
3	2	2	55	117	133	62.9	1981	26.9	15.2

Wk	Str	Diet	Cage	DFI	PDFI	EM	W	WC	T
3	2	3	48	150	138	68.6	2021	40.4	15.2
3	2	4	57	116	126	62.1	1900	0	15.2
3	2	5	52	125	141	63.3	2112	53.8	15.2
3	2	6	56	135	133	48.6	2062	53.8	15.2
3	2	7	42	147	137	67	2021	40.4	15.2
3	2	8	46	143	134	67	1981	26.9	15.2
3	2	9	43	141	144	63.9	2152	67.3	15.2
3	2	10	51	130	133	65	1981	26.9	15.2
3	1	1	62	122	108	60.7	1588	-53.8	15.2
3	1	2	76	131	120	61.2	1750	0	15.2
3	1	3	63	116	119	58.1	1750	0	15.2
3	1	4	69	143	136	52.5	1992	80.8	15.2
3	1	5	73	102	111	49.6	1660	-13.5	15.2
3	1	6	70	130	118	55.9	1750	0	15.2
3	1	7	74	133	130	58.7	1862	53.8	15.2
3	1	8	68	117	121	53.4	1790	13.5	15.2
3	1	9	72	107	115	52.6	1700	0	15.2
3	1	10	71	118	123	59.1	1790	13.5	15.2
3	2	1	77	138	119	64.8	1769	-26.9	15.2
3	2	2	75	138	129	61.6	1940	13.5	15.2
3	2	3	65	128	129	45.7	2021	40.4	15.2
3	2	4	78	124	129	54.1	1981	26.9	15.2
3	2	5	64	139	150	76.3	2142	80.8	15.2
3	2	6	67	127	124	57.3	1900	0	15.2
3	2	7	80	137	135	60.5	2021	40.4	15.2
3	2	8	61	155	135	62.2	2021	40.4	15.2
3	2	9	79	140	138	65.7	2012	53.8	15.2
3	2	10	66	138	142	64.3	2102	67.3	15.2
3	1	1	86	129	119	54.4	1740	13.5	15.2
3	1	2	85	113	116	62.5	1660	-13.5	15.2
3	1	3	97	110	120	56	1740	13.5	15.2
3	1	4	82	127	123	55.2	1781	26.9	15.2
3	1	5	93	121	129	63.2	1821	40.4	15.2
3	1	6	81	118	114	48.8	1700	0	15.2
3	1	7	90	134	117	47.7	1740	13.5	15.2
3	1	8	92	104	118	58.7	1700	0	15.2
3	1	9	99	112	126	55.5	1821	40.4	15.2
3	1	10	95	117	136	57.6	1942	80.8	15.2
3	2	1	89	126	129	58.7	1931	26.9	15.2
3	2	2	83	142	133	60.6	1971	40.4	15.2
3	2	3	87	125	126	67.6	1850	0	15.2
3	2	4	94	150	144	71.7	2052	67.3	15.2
3	2	5	100	131	143	47.3	2173	107.7	15.2
3	2	6	88	122	116	61.7	1719	-26.9	15.2
3	2	7	91	141	137	63.8	2012	53.8	15.2
3	2	8	84	130	131	70.9	1890	13.5	15.2
3	2	9	96	111	123	58.8	1850	0	15.2
3	2	10	98	140	133	51.3	2012	53.8	15.2
3	1	1	109	114	112	58	1610	-13.5	15.2
3	1	2	114	108	109	44.8	1600	0	15.2
3	1	3	113	131	125	53.4	1762	53.8	15.2
3	1	4	120	94	113	47.9	1640	13.5	15.2
3	1	5	106	93	118	55.1	1690	13.5	15.2
3	1	6	119	129	117	54.6	1690	13.5	15.2
3	1	7	118	88	105	34.8	1600	0	15.2
3	1	8	107	132	122	51.1	1771	40.4	15.2
3	1	9	116	123	122	57	1731	26.9	15.2

Wk	Str	Diet	Cage	DFI	PDFI	EM	W	WC	T
3	1	10	108	110	112	57	1610	-13.5	15.2
3	2	1	105	120	120	54.6	1800	0	15.2
3	2	2	117	140	132	65.6	1871	40.4	15.2
3	2	3	104	121	124	63.4	1790	13.5	15.2
3	2	4	111	135	131	55	1912	53.8	15.2
3	2	5	102	121	126	62.6	1840	13.5	15.2
3	2	6	115	120	120	56.3	1800	0	15.2
3	2	7	103	136	132	67.3	1871	40.4	15.2
3	2	8	110	128	122	61.1	1800	0	15.2
3	2	9	112	127	130	57.3	1921	40.4	15.2
3	2	10	101	158	140	57.8	2042	80.8	15.2
7	1	1	12	131	119	60.7	1869	36.2	21.4
7	1	2	14	98	118	65	1829	24.1	21.4
7	1	3	8	129	125	56.7	2119	36.2	21.4
7	1	4	19	105	119	49.6	2019	36.2	21.4
7	1	5	17	107	122	76.2	1829	24.1	21.4
7	1	6	9	119	119	45.3	2009	48.3	21.4
7	1	7	15	99	112	57.9	1729	24.1	21.4
7	1	8	13	121	125	61.9	2009	48.3	21.4
7	1	9	2	116	120	58.2	1979	24.1	21.4
7	1	10	20	120	121	64.9	1990	12.1	21.4
7	2	1	11	125	126	63.3	2069	36.2	21.4
7	2	2	7	123	127	64.9	2129	24.1	21.4
7	2	3	4	125	131	64.5	2219	36.2	21.4
7	2	4	16	127	134	64.9	2259	48.3	21.4
7	2	5	3	108	133	81.3	2129	24.1	21.4
7	2	6	5	131	132	62.7	2269	36.2	21.4
7	2	7	6	119	124	65.1	2029	24.1	21.4
7	2	8	10	151	134	61.1	2309	48.3	21.4
7	2	9	1	123	134	67	2198	60.3	21.4
7	2	10	18	123	136	66.6	2309	48.3	21.4
7	1	1	38	140	118	56.9	1929	24.1	21.4
7	1	2	27	119	121	60.5	1979	24.1	21.4
7	1	3	33	117	118	58.7	1929	24.1	21.4
7	1	4	34	99	118	61.4	1879	24.1	21.4
7	1	5	26	99	116	53.5	1929	24.1	21.4
7	1	6	25	120	118	65.7	1890	12.1	21.4
7	1	7	40	129	119	57.1	1919	36.2	21.4
7	1	8	37	111	125	64.9	1959	48.3	21.4
7	1	9	21	100	117	59.9	1879	24.1	21.4
7	1	10	22	107	113	51.7	1829	24.1	21.4
7	2	1	30	157	131	61.9	2209	48.3	21.4
7	2	2	28	123	128	68.2	2129	24.1	21.4
7	2	3	39	137	127	65.3	2190	12.1	21.4
7	2	4	35	143	141	65.9	2388	72.4	21.4
7	2	5	31	116	126	68.6	2090	12.1	21.4
7	2	6	36	111	127	61.9	2059	48.3	21.4
7	2	7	29	147	137	69.9	2309	48.3	21.4
7	2	8	23	110	129	63.5	2169	36.2	21.4
7	2	9	24	138	135	70.9	2269	36.2	21.4
7	2	10	32	119	132	60.7	2319	36.2	21.4
7	1	1	49	124	119	59.6	1929	24.1	21.4
7	1	2	59	124	120	60	1919	36.2	21.4
7	1	3	54	117	118	57	1990	12.1	21.4
7	1	4	47	129	124	59.2	2069	36.2	21.4
7	1	5	41	126	118	52.5	2100	0	21.4
7	1	6	45	139	121	62.3	1919	36.2	21.4

Wk	Str	Diet	Cage	DFI	PDFI	EM	W	WC	T
7	1	7	58	110	117	59.5	1819	36.2	21.4
7	1	8	50	95	110	65.9	1710	-12.1	21.4
7	1	9	60	143	122	53.6	2009	48.3	21.4
7	1	10	53	135	127	64	1938	72.4	21.4
7	2	1	44	138	126	56.1	2109	48.3	21.4
7	2	2	55	115	122	56.8	2079	24.1	21.4
7	2	3	48	140	127	59.2	2169	36.2	21.4
7	2	4	57	106	130	69.6	2059	48.3	21.4
7	2	5	52	124	134	62.3	2309	48.3	21.4
7	2	6	56	126	126	52.6	2219	36.2	21.4
7	2	7	42	138	138	73.4	2248	60.3	21.4
7	2	8	46	135	138	75.8	2198	60.3	21.4
7	2	9	43	128	133	62.7	2319	36.2	21.4
7	2	10	51	111	128	63.8	2119	36.2	21.4
7	1	1	62	134	113	62.6	1669	36.2	21.4
7	1	2	76	138	118	58.6	1869	36.2	21.4
7	1	3	63	119	119	61.2	1869	36.2	21.4
7	1	4	69	137	127	65.5	2129	24.1	21.4
7	1	5	73	101	112	57.5	1729	24.1	21.4
7	1	6	70	130	119	61.8	1869	36.2	21.4
7	1	7	74	126	118	60.1	1940	12.1	21.4
7	1	8	68	118	120	59.2	1919	36.2	21.4
7	1	9	72	99	114	59.1	1779	24.1	21.4
7	1	10	71	107	118	62.4	1879	24.1	21.4
7	2	1	77	129	118	58.1	1869	36.2	21.4
7	2	2	75	133	125	61	2069	36.2	21.4
7	2	3	65	113	120	47.5	2129	24.1	21.4
7	2	4	78	114	129	59	2159	48.3	21.4
7	2	5	64	140	140	72.6	2359	48.3	21.4
7	2	6	67	120	122	62.9	1979	24.1	21.4
7	2	7	80	132	131	61.1	2209	48.3	21.4
7	2	8	61	140	138	79.1	2209	48.3	21.4
7	2	9	79	130	124	56.3	2129	24.1	21.4
7	2	10	66	118	129	63.9	2229	24.1	21.4
7	1	1	86	118	116	61.1	1829	24.1	21.4
7	1	2	85	114	109	58.9	1690	12.1	21.4
7	1	3	97	116	118	59.7	1869	36.2	21.4
7	1	4	82	115	114	58.2	1840	12.1	21.4
7	1	5	93	107	119	61.3	1929	24.1	21.4
7	1	6	81	109	111	57.9	1740	12.1	21.4
7	1	7	90	127	117	55	1869	36.2	21.4
7	1	8	92	107	110	50	1779	24.1	21.4
7	1	9	99	123	124	59.9	2009	48.3	21.4
7	1	10	95	115	122	62.7	2040	12.1	21.4
7	2	1	89	130	119	59.6	1990	12.1	21.4
7	2	2	83	129	122	62.8	2040	12.1	21.4
7	2	3	87	123	120	63.2	1929	24.1	21.4
7	2	4	94	130	134	71.3	2219	36.2	21.4
7	2	5	100	118	138	64.3	2409	48.3	21.4
7	2	6	88	117	112	46.5	1819	36.2	21.4
7	2	7	91	123	122	58.1	2090	12.1	21.4
7	2	8	84	120	126	66.9	2019	36.2	21.4
7	2	9	96	96	116	52.4	1929	24.1	21.4
7	2	10	98	110	122	60	2090	12.1	21.4
7	1	1	109	120	116	65.4	1719	36.2	21.4
7	1	2	114	113	111	51.8	1719	36.2	21.4
7	1	3	113	124	119	57.2	1919	36.2	21.4

Wk	Str	Diet	Cage	DFI	PDFI	EM	W	WC	T
7	1	4	120	114	121	60	1848	60.3	21.4
7	1	5	106	92	107	55.3	1700	0	21.4
7	1	6	119	121	120	60.1	1859	48.3	21.4
7	1	7	118	121	114	60.2	1719	36.2	21.4
7	1	8	107	111	118	61.1	1879	24.1	21.4
7	1	9	116	107	116	53.8	1869	36.2	21.4
7	1	10	108	108	113	57.1	1719	36.2	21.4
7	2	1	105	121	119	63.4	1879	24.1	21.4
7	2	2	117	125	124	61.5	2019	36.2	21.4
7	2	3	104	121	122	64.9	1919	36.2	21.4
7	2	4	111	115	127	60	2109	48.3	21.4
7	2	5	102	116	121	65.9	1929	24.1	21.4
7	2	6	115	117	120	59.4	1919	36.2	21.4
7	2	7	103	132	124	60.9	2019	36.2	21.4
7	2	8	110	116	120	60.4	1919	36.2	21.4
7	2	9	112	129	129	63.3	2109	48.3	21.4
7	2	10	101	149	137	65.3	2298	60.3	21.4
11	1	1	12	133	116	58.8	1979	25	23.7
11	1	2	14	103	115	60.7	1929	25	23.7
11	1	3	8	134	122	61.7	2189	12.5	23.7
11	1	4	19	104	116	54.4	2089	12.5	23.7
11	1	5	17	114	113	62.6	1889	12.5	23.7
11	1	6	9	123	119	47.2	2168	37.5	23.7
11	1	7	15	111	110	62.2	1789	12.5	23.7
11	1	8	13	120	122	63.9	2129	25	23.7
11	1	9	2	103	114	51.6	2039	12.5	23.7
11	1	10	20	122	124	65.6	2118	37.5	23.7
11	2	1	11	130	122	73.2	2100	0	23.7
11	2	2	7	116	121	53.4	2229	25	23.7
11	2	3	4	119	129	65.2	2329	25	23.7
11	2	4	16	127	129	63.2	2379	25	23.7
11	2	5	3	109	123	64.4	2189	12.5	23.7
11	2	6	5	131	130	66.5	2379	25	23.7
11	2	7	6	117	120	63.8	2089	12.5	23.7
11	2	8	10	140	127	60.1	2389	12.5	23.7
11	2	9	1	116	126	73.6	2250	0	23.7
11	2	10	18	120	129	58.3	2429	25	23.7
11	1	1	38	137	116	61.7	1989	12.5	23.7
11	1	2	27	121	121	63.7	2079	25	23.7
11	1	3	33	119	114	56.7	1989	12.5	23.7
11	1	4	34	110	118	69.6	1939	12.5	23.7
11	1	5	26	97	110	47	1989	12.5	23.7
11	1	6	25	128	117	66.9	1939	12.5	23.7
11	1	7	40	119	115	51.8	2029	25	23.7
11	1	8	37	105	121	70.7	2039	12.5	23.7
11	1	9	21	103	117	59.7	1979	25	23.7
11	1	10	22	109	117	64.4	1929	25	23.7
11	2	1	30	136	121	60.3	2250	0	23.7
11	2	2	28	124	122	69.1	2150	0	23.7
11	2	3	39	121	125	66.4	2239	12.5	23.7
11	2	4	35	132	135	68.2	2529	25	23.7
11	2	5	31	103	128	68.5	2218	37.5	23.7
11	2	6	36	109	113	57.8	2061	-12.5	23.7
11	2	7	29	136	130	68.6	2389	12.5	23.7
11	2	8	23	119	123	55.4	2279	25	23.7
11	2	9	24	131	129	69.3	2339	12.5	23.7
11	2	10	32	106	126	57.3	2389	12.5	23.7

Wk	Str	Diet	Cage	DFI	PDFI	EM	W	WC	T
11	1	1	49	133	118	60.2	2029	25	23.7
11	1	2	59	119	114	62.5	1950	0	23.7
11	1	3	54	120	121	57.9	2118	37.5	23.7
11	1	4	47	129	129	63.5	2257	50	23.7
11	1	5	41	122	121	55.3	2179	25	23.7
11	1	6	45	126	119	61.8	2029	25	23.7
11	1	7	58	108	105	62.2	1771	-25	23.7
11	1	8	50	111	110	59.1	1779	25	23.7
11	1	9	60	139	122	56.2	2168	37.5	23.7
11	1	10	53	132	119	65.2	2039	12.5	23.7
11	2	1	44	121	117	56.5	2150	0	23.7
11	2	2	55	117	119	58.2	2139	12.5	23.7
11	2	3	48	139	125	65.3	2239	12.5	23.7
11	2	4	57	102	112	39.2	2139	12.5	23.7
11	2	5	52	118	126	65.7	2350	0	23.7
11	2	6	56	127	124	54.7	2329	25	23.7
11	2	7	42	129	130	65.5	2379	25	23.7
11	2	8	46	128	127	67.8	2289	12.5	23.7
11	2	9	43	146	128	55.5	2429	25	23.7
11	2	10	51	113	125	62.8	2229	25	23.7
11	1	1	62	133	111	61.1	1779	25	23.7
11	1	2	76	127	118	62.6	1979	25	23.7
11	1	3	63	114	111	60.6	1900	0	23.7
11	1	4	69	134	126	66.7	2229	25	23.7
11	1	5	73	108	111	56.6	1829	25	23.7
11	1	6	70	124	116	64.4	1939	12.5	23.7
11	1	7	74	127	116	61	1989	12.5	23.7
11	1	8	68	117	105	40.1	1950	0	23.7
11	1	9	72	99	108	59.1	1800	0	23.7
11	1	10	71	101	104	48	1861	-12.5	23.7
11	2	1	77	138	114	60.7	1939	12.5	23.7
11	2	2	75	120	126	62.3	2218	37.5	23.7
11	2	3	65	93	108	46.6	2071	-25	23.7
11	2	4	78	110	119	58.7	2200	0	23.7
11	2	5	64	140	134	74.4	2439	12.5	23.7
11	2	6	67	120	113	57.2	2000	0	23.7
11	2	7	80	124	123	64.1	2250	0	23.7
11	2	8	61	145	132	75.2	2329	25	23.7
11	2	9	79	128	123	63.9	2189	12.5	23.7
11	2	10	66	123	124	59.8	2289	12.5	23.7
11	1	1	86	121	112	65.9	1850	0	23.7
11	1	2	85	117	108	66.3	1700	0	23.7
11	1	3	97	118	114	61.4	1939	12.5	23.7
11	1	4	82	108	106	56.6	1811	-12.5	23.7
11	1	5	93	110	119	68.4	1989	12.5	23.7
11	1	6	81	120	108	56.7	1789	12.5	23.7
11	1	7	90	128	112	56	1939	12.5	23.7
11	1	8	92	115	115	62.1	1879	25	23.7
11	1	9	99	118	119	60.8	2089	12.5	23.7
11	1	10	95	104	119	62.4	2089	12.5	23.7
11	2	1	89	128	116	58	2039	12.5	23.7
11	2	2	83	124	119	61.2	2089	12.5	23.7
11	2	3	87	120	115	60.1	1989	12.5	23.7
11	2	4	94	128	125	64.1	2289	12.5	23.7
11	2	5	100	114	125	70.8	2371	-25	23.7
11	2	6	88	120	113	69.6	1850	0	23.7
11	2	7	91	120	123	61.9	2179	25	23.7

Wk	Str	Diet	Cage	DFI	PDFI	EM	W	WC	T
11	2	8	84	114	119	60.8	2089	12.5	23.7
11	2	9	96	101	108	56.4	1911	-12.5	23.7
11	2	10	98	109	117	60.4	2100	0	23.7
11	1	1	109	130	117	65.6	1868	37.5	23.7
11	1	2	114	110	103	58.1	1711	-12.5	23.7
11	1	3	113	121	115	59.5	1989	12.5	23.7
11	1	4	120	116	115	62.4	1939	12.5	23.7
11	1	5	106	98	110	57.7	1779	25	23.7
11	1	6	119	129	113	58.8	1939	12.5	23.7
11	1	7	118	131	117	64	1868	37.5	23.7
11	1	8	107	125	116	59.1	1979	25	23.7
11	1	9	116	110	116	58.9	1979	25	23.7
11	1	10	108	106	109	58.6	1789	12.5	23.7
11	2	1	105	112	111	53.2	1939	12.5	23.7
11	2	2	117	114	117	63.3	2050	0	23.7
11	2	3	104	111	117	64.1	1989	12.5	23.7
11	2	4	111	126	122	61.6	2189	12.5	23.7
11	2	5	102	120	120	64.3	2029	25	23.7
11	2	6	115	115	109	50.2	1950	0	23.7
11	2	7	103	134	124	68.5	2129	25	23.7
11	2	8	110	116	119	69.7	1989	12.5	23.7
11	2	9	112	124	120	58.4	2189	12.5	23.7
11	2	10	101	136	130	69.8	2389	12.5	23.7

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