BIOLOGICAL AND ECONOMIC RESPONSE OF LAYING HENS TO DIETARY LYSINE AND ENERGY CONTENTS DURING PEAK AND LATE PRODUCTION PERIODS

by

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DECLARATION

The experimental work described in this dissertation was carried out in the Discipline of Animal Science and Poultry Science, School of Agricultural Sciences and Agribusiness, Faculty of Science and Agriculture, University of Natal, Pietermaritzburg, from July 2000 to April 2001, under the supervision of Mr Stephen Slippers, and co-supervision of Professor Rob Gous.

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any other University. Where use has been made of the work of others, it has been duly acknowledged in the text.

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TABLE OF CONTENTS

ABSTRACT

The effect of dietary energy and amino acid contents during the peak of production of laying hens has been well investigated, but little is known about the late production period. In most of the previous studies the focus has been on improving the performance of laying hens with little, if any, consideration of the costs of achieving the maximum performance.

The aim of the present study was, (i) to investigate the effect of dietary lysine and energy contents on the performance of laying hens (ii) to find out whether young (30-40 weeks) and old hens (60-70 weeks) perform the same at given dietary lysine and energy contents, and (iii) to determine the differences in income and costs generated by young and old laying hens. It was hypothesised that young laying hens will perform better and yield more income at given dietary lysine and energy contents than old hens.

Two experiments were conducted, during peak (30-40 weeks) and late production period (60-70 weeks) with 240 Lohmann Brown laying hens. For the first experiment, four basal diets, which were a combination of two lysine and two energy levels, were supplied by a commercial feed company. These basal diets were blended with one another in different proportions to produce 15 experimental diets, resulting in five lysine and three energy levels. In the second experiment a feed formulating program (WINFEED) was used to formulate four basal diets with lysine and energy levels that were intended to be close to those used in experiment 1. Due to a blending error, diets with three lysine and five energy levels were produced. This error made it impossible to compare the results of the early and late production period, as originally intended. During both experiments, each bird was allocated between 1.4 and 2 kg feed at the start of each week, when feed was weighed. Egg numbers were recorded daily, at the same time each day, and mean egg weight was recorded by weighing eggs on three consecutive days during each week.

It was found that the dietary lysine contents used in both experiments were sufficient to support maximum egg production and that resulted in no statistically significant differences ($p>0.05$) between treatments being observed in egg production traits (rate of lay, egg weight and egg output). A significant effect of dietary energy content was observed on feed intake, which confirmed that dietary energy content had a significant but indirect effect on

egg production, through its effect on the amount of dietary lysine consumed. Older birds were found to be producing 21 g less egg material per day than younger hens, at a given (comparable) dietary lysine and energy content. This result confirmed that older hens require more nutrients to produce a given quantity of egg material. Since the performance of old hens was lower at a given dietary lysine and energy content, the profit generated was also lower. Younger hens generated numerically higher returns than the predicted returns for older hens, at any given combination of dietary lysine and energy tested. However, it was not possible to verify the results statistically, because the expected responses used for older hens were predicted from the results of young hens. In both ages (over the range of dietary lysine and energy contents used) highest returns were realised with the combination of lowest dietary energy and all lysine contents. The effect of a change in egg price was felt more with hens producing heavier egg at both ages, with young hens being more affected than the old hens. The results from these experiments give some indication on trends of returns for hens of both ages, although the economic optimum combinations of dietary energy and lysine could not be predicted (because of the dietary lysine and energy contents used, that were all sufficient to support maximum egg production).

GENERAL INTRODUCTION

In all animal production industries, input costs account for at least 80 % of income derived from the sale of product, which is also the case in poultry production. The relationship between the value of the product produced and the value of the resources used for production determine the profitability of the farm business. For these industries to survive they must make sure that the value of the products they produce exceed the value of the production resources (inputs) used.

The inclusion rate of maize in poultry ration is about 60%, and with the expected increase in maize price of R300/t most poultry producers will be operating unprofitably. For commercial egg producers to be able to survive in such a situation the egg price must increase by 30 to 40 c/dozen. Egg producers find it difficult to increase their egg prices even under such circumstances since the shop owners to a large extent dictate the price they will pay, especially when it comes to promotions in a desperate effort to remain competitive. That just shows the magnitude of the effect of input cost on poultry production as a whole.

Inputs used in commercial egg production include feedstuffs providing energy, amino acids, minerals and vitamins. The amount of nutrients that can be obtained from some feedstuffs and those required by the birds are usually known, but combining the feed-stuffs to make a feed that will provide all sufficient nutrients required is complex. Although the amino acid and energy requirements for a flock of hens is known, the amounts included in the diet can be varied to achieve the same performance, because hens alter their intake accordingly. But in order to maximise profit in the enterprise the correct amino acid and energy contents need to be chosen carefully, as these will vary depending on the relative costs of the nutrients and the price obtained for eggs.

The amount of dietary lysine required will vary depending on the quantity of other amino acids in the diet, age of the birds and the energy content of the feed. As the birds grow older their amino acid requirements for maintenance increase and therefore the amount required from the diet also increases. Dietary energy content affects the amount required through its effect on the amount of feed that the birds will consume.

The profitability on an egg production unit is a function of the costs of the feed used, age of the birds and the value of the product produced. Feed costs are known to increase with increasing dietary amino acid and energy contents, together with the quantity of that particular feed consumed. It is well known that performance drops as the hen ages. In other businesses the replacement of machinery is done when the repair and maintenance cost exceed the income generated by that machine and so it is also the case with egg production. The producer must make sure that the value of the product produced exceeds the value of the feed used, in order for the business to remain profitable.

Therefore for commercial egg production a sound knowledge of nutrition and cost-benefit relationships is a requirement for profitability. A producer must know how the two concepts can be combined for the benefit of the business. This thesis investigates the effect of age on the performance of laying hens, and their response to a limiting amino acid, and examines the complex relationships between the cost of ingredients supplying the nutrients essential for performance and the revenue obtained for the resultant product. The objective of the study was to determine the principles to be considered when deciding upon feeds, and whether these differ depending on the level of performance of the hens.

CHAPTER 1

A REVIEW OF THE FACTORS AFFECTING THE UTILIZATION EFFICIENCY OF DIETARY AMINO ACIDS BY LAYING HENS

1.1 INTRODUCTION

In general terms efficiency can be defined as a measure of how much one can get in return (output) from what were put in. Efficiency of amino acid utilization refers to how much amino acid is deposited in animal products from the amino acid consumed by the animal. For egg production by laying hens efficiency is determined by comparing the amount of amino acid deposited in the egg with the estimate of the amount required to produce a given weight of egg (Goddard, 1997). The expected amino acid content of the egg needs to be known for this comparison to be made. But more importantly, the amount of amino acid required per gram of egg output needs to be measured, and it is important to determine whether this varies as the hen ages.

Amino acids are costly components of poultry feeds, so to stay in production it is necessary to maximize their efficiency of utilization. The only way of minimising the amino acid costs as a poultry producer is through achieving maximum efficiency of utilization. To achieve this we must know the factors affecting their efficiency, in order to make the conditions conducive for obtaining it.

Efficiency of utilization of amino acid in laying hens is affected by factors such as dietary energy concentration, amino acid balance in the diet, age of the birds, rate of lay and the proportions of the egg components. Gous *et al.* (1987) suggested that amino acid requirements for laying hens should not be stated as a proportion of diet or as a ratio with dietary energy, but rather that the optimum daily intake of each amino acid should be calculated according to the method of Fisher *et al.* (1973), together with the optimum energy concentration (Morris, 1968). This is because the optimum amino acid varies, depending on the amount of feed a bird can consume, which is indirectly influenced by the energy concentration of that feed.

With laying hens the efficiency of amino acid utilization drops due to a decreasing rate of lay, which may be below 50% after 70 weeks of age. The balance of amino acids in the diet has an influence on their utilization since the efficiency of utilization of some is dependent on the quantity of others which are antagonistic to them (D'Mello and Lewis, 1970). The proportions of egg components (shell, albumen and yolk) produced has an influence on the efficiency of amino acid utilization since these components vary in amino acid content. Efficiency will depend on which component is dominating. Eggs with high yolk : albumen ratio will have high amino acid utilisation efficiency, since yolk production requires more amino acids when compared to albumen.

1.2 DETERMINATION OF UTILIZATION EFFICIENCY

The efficiency of amino acid utilization for egg production can be determined by comparing the amount of amino acid deposited in the egg with the estimate of the amount required to produce a given weight of egg (Goddard, 1997). The conversion efficiency of dietary amino acid to egg protein by laying hens was calculated by Fisher (1980) and MacDonald and Morris (1985), and it was found to be ranging between 74 and 85%. Utilization efficiencies for the amino acid lysine by hens are shown in Table 1.1. Most of the researchers used 7.93 mg/g to represent the amount of lysine per gram of egg, the value that was suggested by Fisher (1967), based on the assumption that egg contains 11.25 percent protein. Pilbrow and Morris (1974) used 7.4 mg/g as the amount of lysine per gram of egg, assuming 12.5 percent crude protein in the egg and 6.6 percent lysine in egg protein.

Table 1.1 *Efficiency of lysine utilization by laying hens*

Researchers	'a'(mg/g egg)[1]	egg (mg/g)[2]	Efficiency
Conner (1982) [3]	10.71	7.93	0.74
Griessel (1980)	10.49	7.93	0.76
Latshaw (1976) [3]	7.89	7.93	1.01
McDonald (1979) [3]	13.29	7.93	0.60
Morris (1981) [3]	8.28	7.93	0.96
Pilbrow and Morris (1974)	9.50	7.40	0.78

1: 'a' = an estimate of the amount of amino acid required to produce 1g of egg output

2: (egg (mg/g) = the amount of amino acid observed in a gram of egg

3: Cited by McDonald and Morris (1985)

A model is available to describe and predict the response of laying hens to different intakes of amino acid intake (the Reading Model - Fisher *et al*., 1973). The response for a group of birds is derived as the average of the individual responses. The shape of the curve for flock-response depends on seven parameters, namely the mean maximum egg output (Emax), variation in Emax, mean body weight (W), variation in W, the correlation between egg output and body weight, and two constants (a and b) representing the quantity of amino acid required per unit egg output and for maintenance per unit of body weight respectively. This model leads to a logical method for the prediction of amino acid requirements as a function of body weight and egg output. When the model is used, it is assumed that each individual bird has a characteristic maximum level of egg output (Emax) and that, for each bird, when $E<Emax$, then $A = aE + bW$; where A = amino acid requirement (mg/ bird d) and W = body weight in kg. It is also assumed that when $A < bW$, $E = 0$, thus excluding negative egg production. When a group of birds is considered, the response is the average of the responses for individual birds.

1.3 DIETARY ENERGY CONCENTRATION

In experiments where dietary energy concentration is investigated, the content of all essential amino acids, including the limiting one, must be held constant and only dietary energy concentration be varied. This will allow for investigation of dietary energy effect without it being confounded with amino acids effect.

The amount of energy that a bird can consume is not constant over all dietary energy concentrations, being lower at low energy levels and higher at high-energy concentrations. Energy was found not to have an influence on egg output directly, but only indirectly through its effect on food intake and, hence, amino acid intake (Gous *et al.*, 1987). If the amino acid content of the feed is held constant and energy content is reduced, feed intake increases which will increase the amino acid intake. But if energy content is increased while amino acid content is kept constant, feed intake will decrease and, hence, amino acid intake will decrease concomitantly.

At low energy concentration, if the amino acid concentration is also low, birds will need to eat a large amount of feed to achieve maximum egg production, which is sometimes impossible. This high feed intake is mostly associated with low egg output, since most of the birds are unable to consume the amino acid quantity required for maximum egg production. If one considers the effect of energy separately from the effect of amino acids, one might be misled into thinking that dietary energy influences egg production. In the methionine experiment conducted by Gous *et al.* (1987), the main effect of energy on both egg weight and egg numbers was significant. However, the difference was seen to have been brought about by the particularly low egg production (both weight and number) associated with the low energy, low methionine treatment. But at the three higher methionine levels, no significant differences existed between energy levels in either egg weight and egg number. When the response in egg weight and number were compared at the lowest methionine concentration with the actual intake of methionine, it was evident that the difference in productivity had not been caused by the low energy concentration, but rather by the low intake of methionine (202 mg/bird/d at 10MJ ME/kg compared with

220 mg/bird/d at 11.70 MJ ME/kg). When the output was expressed as a function of intake of the limiting nutrients, the problem was resolved.

It is still frequently stated that birds eat to satisfy their need for energy. If this statement were true, the birds would attempt to eat a constant amount of energy, irrespective of the energy or nutrient concentrations in the diet, and the requirement for amino acids could then be expressed as a constant ratio of the energy supply. However, Morris (1968) has shown that birds consume less energy as the energy concentration of the diet is reduced and over-consume energy as the energy concentration is increased. It was found by Gous *et al.* (1987) that birds tend to consume more energy as dietary energy concentration was increased. This leads us to conclude that dietary energy concentration does not affect the efficiency of amino acid utilization directly, but indirectly since the optimum daily intake of each amino acid should be calculated according to the method of Fisher *et al.* (1973), together with the optimum energy concentration (Morris, 1968).

1.4 AGE OF THE BIRDS AND RATE OF LAY

As laying birds grow older the value of the products they produce tend to become less than the value of the feed they consume (Pilbrow and Morris, 1974). This means that their marginal costs tend to be greater than their marginal income as they grow older. If it were not like that, we would keep birds in production until they died. Fisher (1970) confirmed this effect and there is no doubt that the net efficiency of utilization of protein declines as the laying cycle progresses. Pilbrow and Morris (1974) found that the relationship between lysine input and egg output did not remain the same throughout the first laying year. They found that the net efficiency of lysine utilization declines, as the birds grow older. It was suggested that one of the causes of declining amino acid utilization efficiency might be the presence of increasing numbers of non-productive hens in older flocks (Pilbrow and Morris, 1974). Such birds are consuming amino acids, whilst not contributing to flock output; that was found to have a substantial effect on estimates of efficiency based upon mean flock responses. This means that age of birds do not affect the efficiency of amino acid utilization directly, but indirectly, through rate of lay.

In all cases where responses to protein have been measured independently in flocks at different stages of the first laying year, nutrient utilization has been lower in the older birds, provided that the rate of lay is lower in the older birds. When responses at similar stages of the first and second years of lay are compared, the older birds are again less efficient if they are laying at a lower rate (Fisher, 1970, data for methionine), but not when rate of lay is the same in the two groups (Wethli and Morris, 1978). This apparent relationship between mean rate of lay in the flock and nutrient utilization directs attention to the same relationship amongst individuals. Gous *et al.* (1987) suggested that the rate at which efficiency of utilization changes with age could be detected with a series of short experiments, repeated at intervals throughout the laying year, rather than a continuous feeding trial.

Eggs are typically laid in cycles or clutches, interrupted by some days or a day without an egg. When the non-laying periods are sufficiently long to cause intermittent variations in the rate of protein synthesis it is to be expected that the utilization of ingested protein will decline, since intake is not adjusted under *ad libitum* feeding to correspond with the needs for synthesis. Figure 1.1 shows some data for calculated methionine utilization in response to rate of lay for individual birds of three ages (Fisher, 1967). The effects of rate of lay can be seen clearly from the figure, with a rapid decline in utilization occurring, as expected, below 50 percent rate of lay in all ages. All three ages had shown different maximum net methionine utilization (105 for 30 to 40, 99 for 45 to 55 and 90 percent for 60 to 70 weeks).

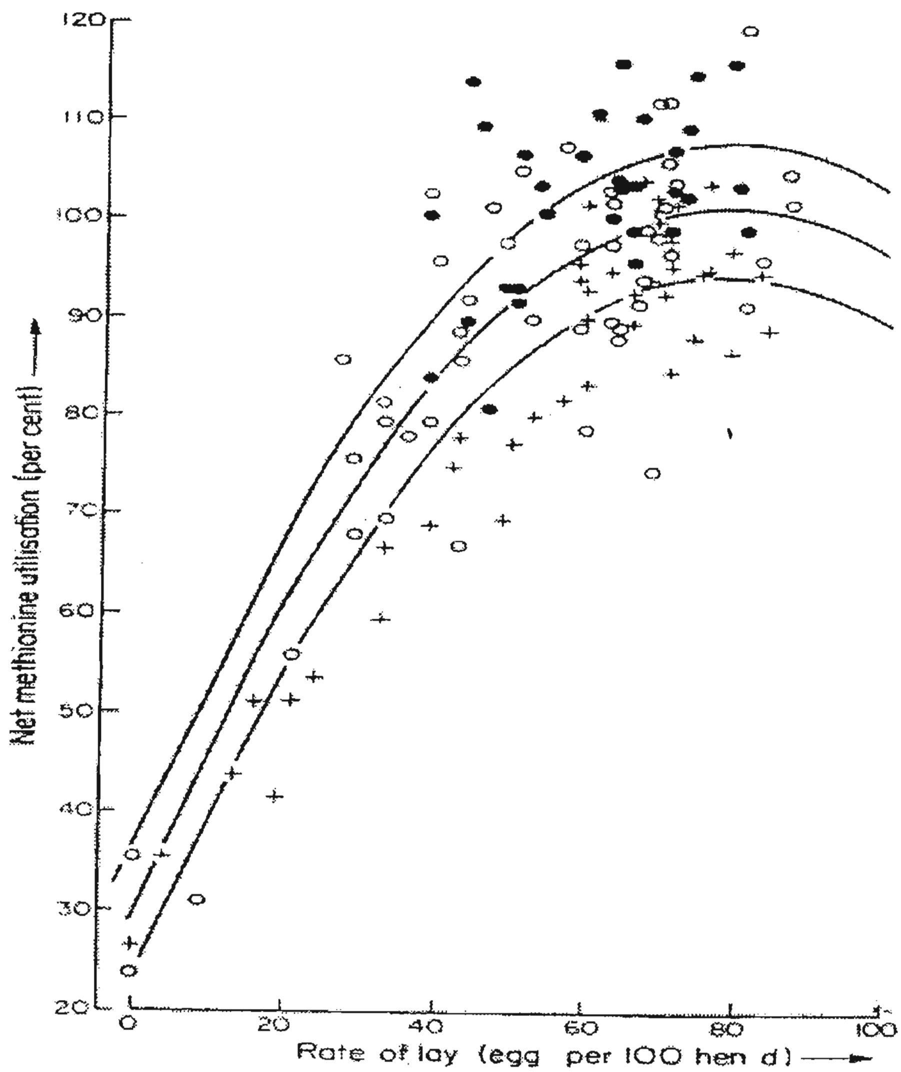

Figure 1.1 *The relationship between net methionine utilisation and rate of lay in individual laying pullets of three ages:- 30 to 40 weeks (•), 45 to 55 weeks (0), 60 to 70 weeks (+) (Fisher, 1976).*

Fig. 1.1 shows that there is an interaction between the rate of lay and age of birds and both factors have an influence on the net amino acid utilization. Young layers tend to utilize amino acid more efficiently when compared to older hens, even if the rate of lay is the same. This means we need more amino acids for older birds to achieve the same level of productivity in younger birds. The important consequence of the change in lysine utilization with age is that the requirement for lysine at an older age cannot be predicted from the information gathered from young pullets. There is a theoretical argument saying that protein requirement must also decline as production declines with age, but this was found to be unsound because the amount of protein required per unit of egg output remains constant. Lysine requirements were found not to decrease with age (Bray, 1968; Jennings *et al.*, 1972; Pilbrow and Morris, 1974).

The decision on what to do when efficiency of amino acid utilization declines due to age of birds can be also considered from an economic point of view. In a situation where a laying hen can be sold at a cost similar to the price for a point-of-lay pullet, it pays to sell laying hens at an earlier age than where a producer does not have a market for old laying hens and pullets depreciation is consequently high. The latter situation applies in most countries around the world, but not in South Africa.

Rose (1997) gave the following summary on force moulting procedures, its influence on hormonal functioning and egg production, and the effect of its length. For the older birds to produce in relation to their amino acid consumption, force moulting must be applied. The force moulting procedures usually involve quantitative and/or qualitative feed restriction, along with reduced photoperiods and/or reduced light intensity. Moulting provides the birds with a rest from egg production and allows time for tissue regeneration, particularly in the oviduct. Egg production declines once a moult has begun and ceases completely after about ten days. The oviduct regresses and its weight declines to about one-tenth of its maximum weight. The ovary also regresses and its weight declines to one-twentieth of its maximum weight. Weight loss of the ovary and oviduct may account for approximately 25 percent of a laying hen's body weight loss during a moult. Progesterone levels are lowered during moulting and this appears to stimulate the feather follicles to start feather regeneration. The loss of feathers in moulting birds is caused by regeneration of new feathers, which push out the old ones. Low nutrient intakes in the early laying period after a moult can stunt feather growth and reduce egg output.

The increase in egg weight as the flock ages is not altered by a moult. Different moulting procedures need to be given to different species, to strains within species, and to birds under different management systems. The length of the egg-laying pause during an induced moult is influenced by the length of the feed restriction period. Increasing the length of the egg pause (up to four weeks in laying chickens) gives an increase in egg numbers and an improvement in egg quality characteristics in the second laying period.

Long periods of feed restriction during moulting result in achievement of uniform body fat losses throughout the flock, and achieve a complete regression of the oviduct. These factors may be important in optimising egg production and egg quality in the second laying period. Figure 1.2 shows the comparison in performance between young pullets, older and moulted laying hens, when fed different concentrations of tryptophan. It can be seen from figure 1.2 that the maximum performance of old moulted hens was very close to those of young laying pullets. It may be concluded that high profit maybe realised by force moulting old hen, but only if it is economically feasible.

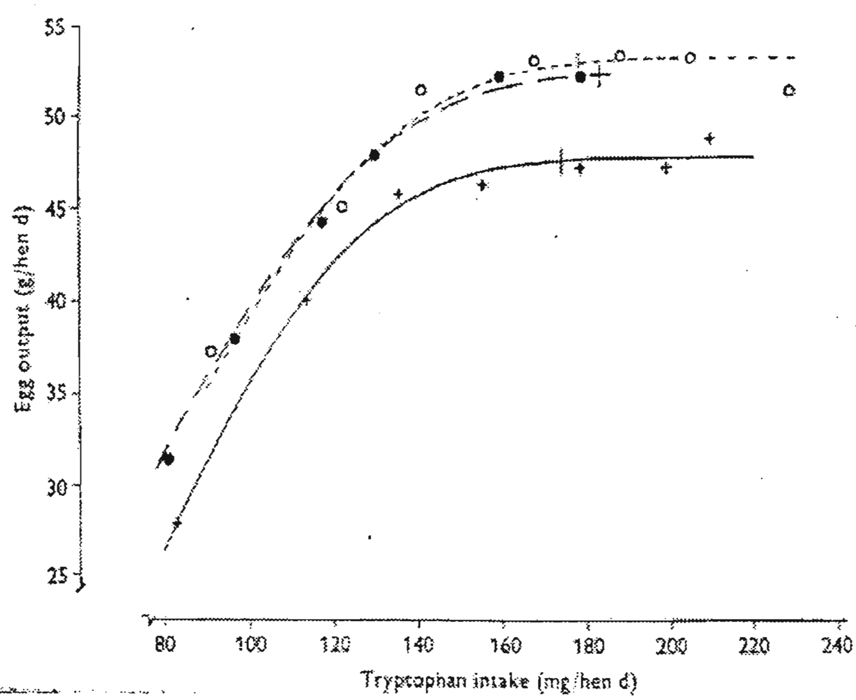

Figure 1.2. *Response to diets supplying different concentrations of tryptophan (From Wethli and Morris, 1978). The fitted response curves were derived by using the Reading model (Fisher et al., 1973). Young pullets, •---•; older pullets, +-----+; moulted hens, o-----o. Vertical marks on the response curve represent optimal tryptophan intakes.*

1.5 INCORRECT BALANCE OF AMINO ACIDS

Amino acid balance refers to the relationship between the amino acid composition of a protein and its biological value. "A protein which provide amino acids in roughly the proportions in which they are required by the body is termed balanced protein: a protein that is low in one or more of the indispensable amino acids is termed an unbalanced protein and has a lower biological value"(Harper, 1958). The more unbalanced the protein is, the lower the efficiency with which it is used and the greater the amount needed in a diet to satisfy the amino acid requirements (Block and Mitchell, 1946 and 1947; Oser, 1951; Almquist, 1953; Mitchell, 1954; Flodin, 1953 and 1957, as cited by Harper (1958)). Incorrect balance of amino acids in the diet may cause a deficiency, toxicity or an antagonism.

1.5.1 Deficiency

A deficiency occurs when at least one amino acid is supplied in a quantity less than required in the diet, while the remaining indispensable amino acids are adequately supplied. The efficiency of utilization of those amino acids supplied in adequate quantities are affected or depressed by the ones that is limiting (Harper *et al.*, 1970). Birds will try to eat as much food in an attempt to consume sufficient amount of the first limiting amino acid. This will lead to excessive intake of those amino acids that are sufficiently supplied, with a subsequent increase in their catabolism. An amino acid deficiency can be corrected by adding a quantity of the first-limiting amino acid to the diet. An amino acid deficiency tends to increase food intake while an imbalance depresses it.

1.5.2 Toxicity

Amino acid toxicity occurs when there is an excessive amount of one amino acid in the feed. It was found that tryptophan ingested in excessive amounts by young growing rats fed a low-protein diet caused severe eye and paw lesions, as well as retarded growth and depressed food intake, and in greater excess can be lethal (Harper et al., 1970). Threonine, on the other hand, was tolerated well and, even in greater excess, has been shown to cause only moderate growth retardation and food intake depression (Harper *et al.*, 1970). Jones (1960) found that excessive dietary L-lysine depresses growth rate and produces toxic symptoms in 14 to 21 day-old chicks fed adequate protein diets. Addition of 5% glycine to a semisynthetic, low-folacin diet depressed growth and produced symptoms of toxicity such as nervousness, tremors, protruding eyes, and occasional paralysis in rats (Naber *et al.*, 1955). Usually no one amino acid is included in the diet in an amount that, by itself, would be considered toxic.

1.5.3 Antagonism

Antagonisms between amino acids occur when the utilization of one amino acid is affected by the quantity of another in the diet. The efficiency of utilization of some amino acids are affected by the concentration of others. There is ample evidence that groups of naturally occurring amino acids can compete *in vitro* with one another for transport sites (Harper et al., 1970). It is generally accepted, however, that even a small surplus of certain amino acids can sometimes increase the need for others. This implies that the requirements for certain amino acids are interdependent. When lysine and arginine interaction was considered, it was found that the growth depression at each dose of excess lysine was overcome by increasing the dietary concentration of arginine (D'Mello and Lewis, 1970). The concentration of arginine required for complete reversal of the ill effects on growth was dependent upon the magnitude of the excess load of lysine. The straight-line correlation found indicated that even a small excess of dietary addition of lysine was likely to increase the quantity of arginine needed. Excess lysine in the diet caused a proportionate drop in the concentration of circulating arginine. Jones (1964) suggested that excessive dietary supplementation of lysine induces an arginine deficiency by decreasing the availability of arginine from casein, gelatin, or from a combination of these products. The primary effect of lysine was thought to be due to increased catabolism of arginine within the chick or competition between lysine and arginine at the renal tubular absorptive surface, either of those results in an early decrease in plasma arginine concentration (Jones *et al.*, 1967). High concentrations of arginine in the diet did not affect growth adversely, but exerted a profound effect on the concentration of plasma lysine, which tends to drop. In order to achieve maximum efficiency of utilization of arginine, lysine concentration in the diet must be considered to be in-relation to it. The growth retardation resulting from the excess addition of arginine to the basal diet low in lysine was completely reversed by supplementation of the diet with lysine.

Interactions between leucine and isoleucine, leucine and valine, and threonine and tryptophan follow similar antagonistic relationships to that of lysine and arginine. Given these relationship, the increase in concentration of one amino acid resulted in an increase in the quantity required of its antagonistic partner. Antagonism can be controlled by supplementation of an amino acid that is structurally similar to the one added in excess. In some instances one amino acid can be antagonistic to two or more other amino acids. Under such circumstance the interaction of that amino acid with the second one is detected by keeping the third one at an adequate concentration in the diet. For example leucine and isoleucine were examined when valine was kept at an adequate concentration in the diet. The concentration of antagonistic amino acid required in the diet may also depend on the ingredients included. It is probable that valine and isoleucine requirements may be unusually high on diets containing a high proportion of maize and maize gluten meal, due to the high concentration of leucine in these products.

1.6 EGG COMPOSITION

The efficiency of amino acid utilization by laying hens is influenced namely size of the egg, which means that it is affected indirectly by the factors affecting egg size, such as age of hens and amino acid content of the feed. There is a significant relationship between egg size and egg component yield. Egg components vary in nutrient content, especially protein and amino acid. The utilization efficiency tends to depend on proportions of egg components and their amino acid content. Several factors have been found to affect the yield of egg components and the relative ratios of yolk and albumen. Cunningham *et al.* (1960) showed the effect of season of the year on egg size. Egg size was also shown to increase linearly with an increase in age of the bird by Clark (1940) and Jeffery (1941). Jeffery (1941) concluded that egg weight was a function of the interaction of age, environmental temperature and body weights. The effect of hen age on amino acid utilisation efficiency is brought by the influence of egg weight on its components. Flock age had significant effects on egg components yield such as percent shell, percent yolk, percent albumen, and percent albumen solids.

The effect of hen age on egg components yield was studied by Fletcher *et al.* (1981) who found that the variation in egg components yield obtained was attributed to the effect of hen age and not due to the effect of hen age on egg weight. Percent yolk increased significantly ($p<0.05$) with increasing flock age from 28.88% for the 26-week-old flock up to 32.82% and 32.63% for the 45 and 58-week-old flocks, respectively. The percentage albumen was found to decrease significantly ($p<0.05$) with increasing flock age from 71.12% for the 26-week-old flock down to 67.37% for the 58-week-old flock. Significant variation ($p<0.05$) was realized in percentage yolk solids between 26 and 45-week-old flocks, but no significant difference was found between the rest of the different age groups (Fletcher *et al.*, 1981).

Albumen solids were found to decrease significantly ($p<0.05$) with increasing flock age from 13.98% for the 26-week-old flock to 12.47% for the 47-week-old flock. Egg weight increased significantly ($p<0.05$) with increasing flock age from 59.54 g for the 29-week-old flock up to 61.66 g for the 62-week-old flock. There was no significant difference in dry shell weight, although the percent shell was found to decrease significantly with increasing age. The decreased percentage shell was suggested to be due to increased egg weight in relation to dry shell weight. With the flock age increasing, the percentage yolk increased significantly from 27.64 for the 29-week-old flock up to 31.44% for the 62-week-old flock (Fletcher *et al.*, 1981). Percentage albumen decreased significantly ($p<0.05$) from 72.36% for the 29-week-old flock, down to 68.56% for the 62- week-old flock. Percentage yolk solids showed a significant improvement ($p<0.05$) for the 62-week-old flock compared to the 53 and 29-week-old flocks. The percentage albumen solids were found to exhibit a significant ($p<0.05$) decrease with increasing flock age from 13.89% for the 29-week-old flock, to 12.51% for the 62-week-old.

Fletcher *et al.* (1983) found that egg weight, yolk weight, yolk percentage, albumen weight and yolk solids increase, while albumen and shell percentage decrease, as a result of increasing flock age. The shell weight and albumen solids apparently did not change. There was a positive relationship between changes in yolk yields with egg weight and hen age. Selecting for larger eggs, older hens, or both could increase yolk yield. The rate of increase in total yolk size was found to be less than the rate of increase in total egg size (Fletcher *et al.*, 1983). At a given egg weight both albumen and shell yield were found to be increasing, but at a decreasing rate, with increasing hen age. Expressed as a percentage, shell yield was found to be a negative function of egg weight. That shows that shell weight increases at a decreasing rate as egg weight becomes greater.

Albumen solids, however, are related to hen's age, but independent of the effect of age on albumen yield. Therefore, older hens were generally found to yield less total albumen (percent) and less solid (more watery) (Fletcher *et al.*, 1983). Greater yolk and albumen weights were observed during late production (Grobas *et al.*, 1999). The proportion of increase in weight with age was more pronounced for the yolk than for the albumen (30.9 vs. 15.3%). That led to greater yolk to albumen ratio (yolk weight/albumen weight) for older than for younger hens (0.365 vs. 0.413; $p<0.001$). Egg weight was 14.4% greater at 74 weeks than at 22 weeks and eggshell plus membrane weight increased by 13.2% for the same age comparison. Similar results were achieved by Whitehead *et al.* (1991), with a significant ($p<0.001$) increase in the proportion of yolk and significant decrease in the proportions of albumen ($p<0.01$) and shell ($p<0.05$) respectively, with age.

Fisher (1980), MacDonald and Morris (1985), Smith (1978a & 1978b) and Goddard (1997) described the protein content of the egg as follows: A typical egg weighs about 58 to 60 g and contains 7 to 7.5 g (11 to 12 %) protein. About 3.1 g (42%) is yolk protein, synthesized in the liver, and about 4 g (54 %) is albumen protein, synthesized mainly in the magnum region of the oviduct, and the remaining 3 to 4 % of the protein is in the shell and its associated membranes.

Table 1.2: *The lysine content of the yolk and albumen, assuming a 60 g egg contains 27 g N/kg yolk and 17 g N/kg albumen (Lunven et al., 1973).*

	Yolk	Albumen
mg lysine/g N	477	378
mg lysine/g (egg component)	12.87	6.42

Values for yolk and albumen lysine content of eggs from hens of different ages (Table 1.3) were calculated using the lysine content of the egg (mg/g) in Table 1.2. Yolk or albumen content of the egg was obtained by multiplying the grams of yolk or albumen with the mg of lysine per g of yolk or albumen. From the regression equations fitted to those values it was observed that there was a slight linear decrease in albumen, while percentage lysine of the egg increase curvelinearly when hen age was increasing (Figure 1.3). The regression equations for lysine content of the yolk and albumen showed a similar response to those of their percentages (Figure 1.4). From Figure 1.4 it can be seen that total lysine content of the egg increase linearly with increasing hen age.

Table 1.3: *Relationship between age of laying hens and the lysine content of the yolk and albumen in eggs*

		Yolk		Albumen		
Age (weeks)	Egg weight (g)	Percent	Lysine (mg)	Percent	Lysine (mg)	Total lysine (mg)
24 [c]	53.8	23.9	165.5	69.5	227.6	393.1
26 [a]	55.1	28.9	204.9	71.1	251.5	456.4
29 [b]	59.5	27.6	211.3	72.4	276.6	487.9
30 [c]	61.5	25.2	199.5	65.4	258.2	457.7
37 [b]	60.9	29.1	228.1	70.9	277.2	505.3
38 [a]	62.5	31.1	250.2	68.9	276.5	526.6
40 [c]	59.2	28.3	215.6	62.3	236.8	452.3
45 [a]	65.1	32.8	274.8	67.2	280.9	555.7
47 [a]	61.8	32.6	259.3	67.4	267.4	526.7
48 [c]	63.4	28.4	231.8	62.7	255.2	487.0
53 [b]	61.6	30.9	244.9	69.1	273.3	518.2
55 [a]	66.0	30.8	261.7	69.2	293.3	553.9
58 [a]	65.7	32.6	275.7	67.4	284.3	560.0
62 [a]	61.7	31.4	249.3	68.6	271.8	521.1
63 [c]	65.5	29.2	246.6	61.9	260.3	506.9

Lysine content of the yolk and albumen for this table were calculated using Lunven's (1973) assumptions. Those values were sourced from the articles by the following authors:

a = Lunven *et al.* (1973)

b = Fletcher *et al.* (1981)

c = Fletcher *et al.* (1983)

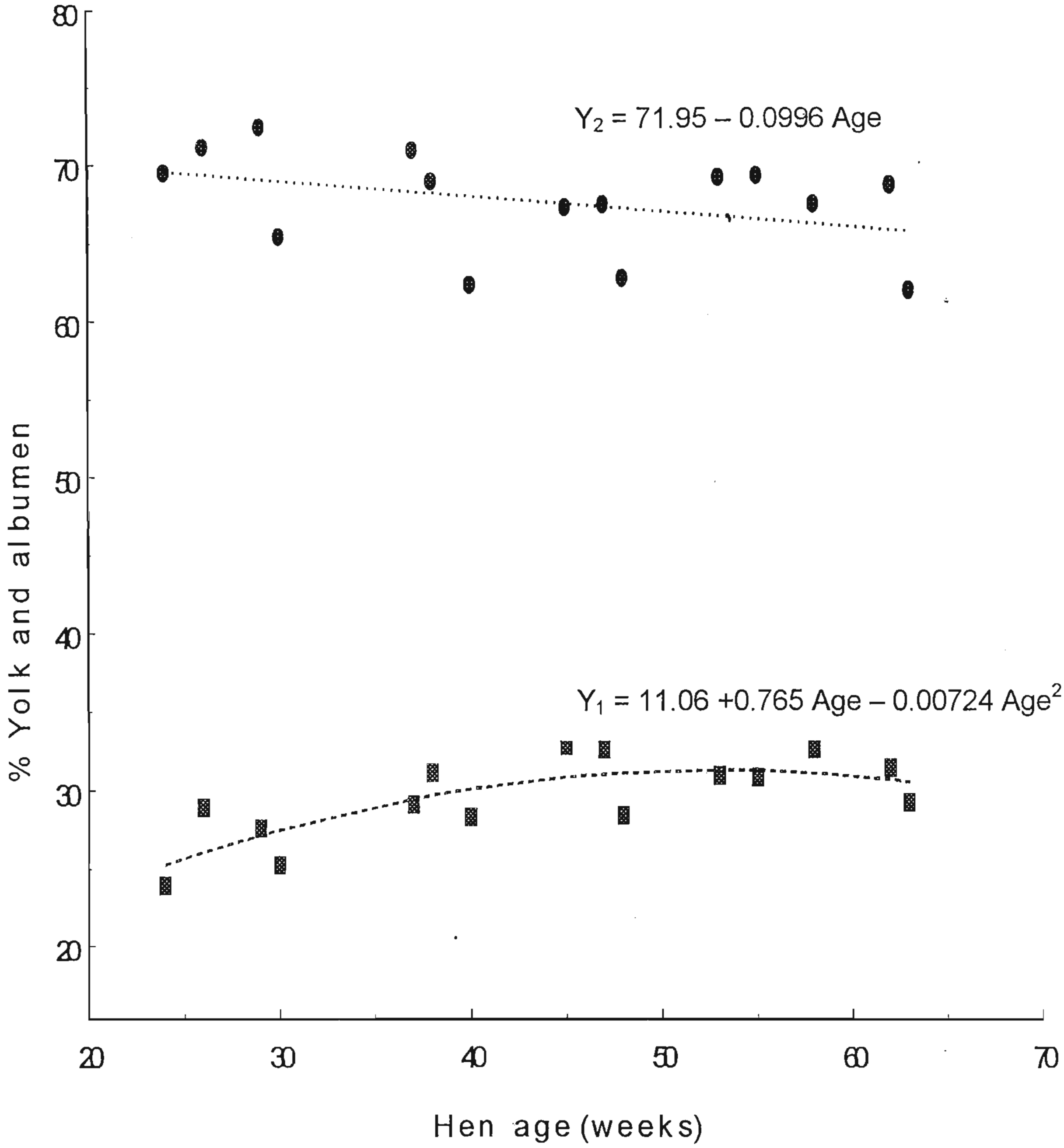

Figure 1.3: *Predicted percentage change in yolk and albumen content of the egg with increasing age of the hens (by regressing their observed values in Table 1.3). Yolk (■) and albumen (•).*

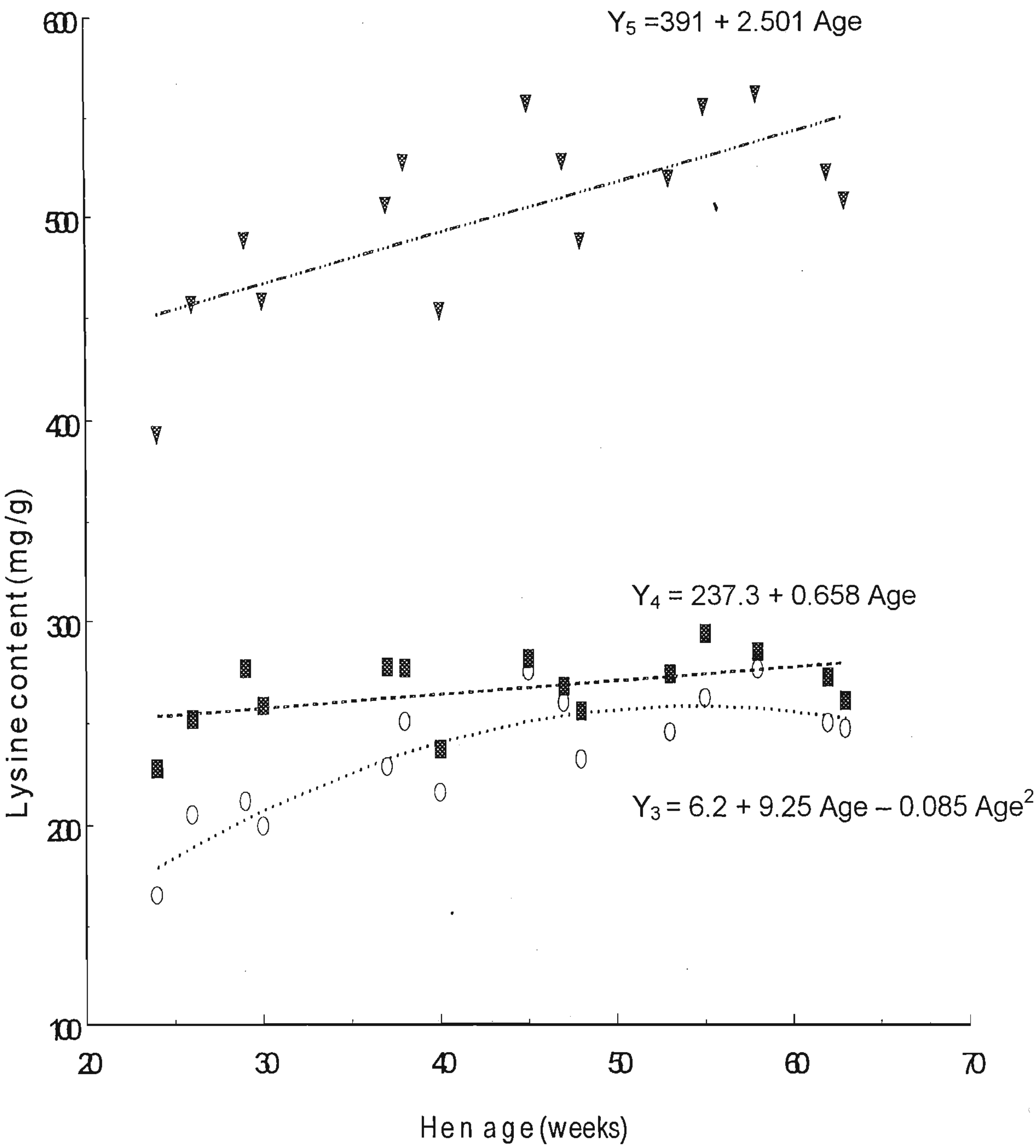

Figure 1.4: *Predicted change in lysine content of yolk, albumen and whole egg with increasing hen age (by regressing their observed values in Table 1.3). Yolk (○), albumen (■) and total (▼).*

CHAPTER 2

RESPONSE OF LAYING HENS TO DIETARY LYSINE AND ENERGY CONTENTS

2.1 INTRODUCTION

The aim of any egg producing company or industry is to produce as many eggs as possible whilst minimising feeding costs. Feed companies supply feeds varying in energy and amino acid contents, and choosing the correct feed from the variety on offer would depend on factors that contribute to profitability in the enterprise, which are: (i) the cost of the feeds in-relation to their energy and amino acid content (ii) the amount of each feed that would be consumed by the laying hens (iii) the level of production being achieved by the flock (not the age, although these are generally related) and (iv) the value obtained by the producer for the eggs.

Under some circumstances the feed containing the highest amino acid contents would be the most profitable, but under other circumstances it may be the least profitable. The objective of this trial was to evaluate feeds containing different combinations of amino acids and energy, typical of the range of feeds that may be produced by a commercial feed company. This evaluation takes the form of feeding the diets to hens in the early and late laying periods, and measuring their responses in egg production (rate of laying and egg weight, both of which contribute to the revenue generated) and feed intake, which contributes to the cost of feeding. The observed responses in egg production were used to predict the expected responses, so that the expected income and feed costs associated with different feed combinations could be predicted by regression. From these predictions the combination of dietary energy and amino acid contents that maximise profit (income over feed cost) would be determined and compared for the young and old hens, to ascertain whether the optimum combinations change with age.

2.2 EXPERIMENT 1 (YOUNG HENS; 30 – 40 WEEKS OF AGE)

2.2.1 Material and methods

2.2.1.1 Birds and management

Lohmann Brown layer pullets were raised from day old to 18 weeks of age at Ukulinga Research farm, where they were fed (ad libitum) layer starter mash from day old to 6 weeks and layer grower mash from the beginning of week seven until they were 18 weeks old. They were then transferred to laying cages in an open-sided house, on 14h light per day. They were fed commercial layer mash from the time they reached 50% lay until they were 30 weeks old. Two hundred and forty birds were randomly chosen from the 2 500 reared to this age. These birds were sub-divided into four body weight categories before being transferred to individual cages, which contains four rows, back to back, each row having two levels of 64 cages. Each cage (43, 41 and 29 cm in length, height and width respectively) was supplied with a nipple drinker and one feeder (with a feeding space of 28 cm wide).

2.2.1.2 Treatments and feeds

The feed company, OTK, provided four feeds that were used in this experiment (a combination of two energy levels and two protein levels). Their ingredient compositions are shown in Table 2.1. Table 2.2 shows the formulated and analysed nutrient content of these four basal diets. These feeds were blended appropriately to give three energy levels and five protein levels, and the end result was fifteen feeding treatments (Table 2.3). Sixteen birds were chosen at random, four from each weight category, per treatment.

Table 2.1: *Composition (g/kg as fed) of the four basal feeds used in the experiment*

	Feed			
	A	B	C	D
Ingredients	HP/LE	LP/LE	HP/HE	LP/HE
Yellow maize	491.5	505.3	485.5	549.7
Fish meal 65	44.0	-	50.0	22.0
Soya oilcake	-	-	0.7	-
Full fat soya	-	11.7	70.0	70.0
Sunflower oilcake	150.0	150.0	150.0	150.0
Maize gluten 60	8.0	-	31.3	-
Hominy chop	-	70.0	-	65.7
Wheat bran	160.0	160.0	26.0	5.0
L-lysine	-	1.3	-	0.1
DL-Methionine	0.2	-	-	-
Sunflower oil	-	-	30.0	27.3
Limestone	87.7	89.7	95.3	96.7
Mono-calcium Phosphate	2.7	7.7	4.7	8.3
Salt (clean)	3.1	4.7	2.9	3.6
Choline Chloride	0.5	0.5	0.5	0.5
Vit + Min Premix (layer)	1.0	1.0	1.0	1.0

Table 2.2: *Calculated and analysed nutrient contents (as fed) of the four basal feeds*

	Feed							
	A		B		C		D	
	HP/LE		LP/LE		HP/HE		LP/HE	
Nutrients	Calc.	Actual	Calc.	Actual	Calc.	Actual	Calc.	Actual
Dry matter (%)	-	88.6	-	88.1	-	89.2	-	88.4
AME (MJ/kg)	10.6	10.5	10.6	10.2	11.8	12.0	11.8	11.4
Protein (g/kg)	164.4	178.8	132.0	127.7	176.1	194.4	146.8	142.4
Lysine (mg/g)	8.5	8.2	6.2	4.9	9.3	8.5	6.8	6.1
Methionine (mg/g)	3.4	3.2	2.5	2.6	3.8	3.8	2.7	2.5
Threonine (mg/g)	4.6	6.2	3.4	3.9	5.1	6.5	3.7	5.0
Arginine (mg/g)	6.7	11.4	4.9	8.2	7.4	11.6	5.4	9.0
Isoleucine (mg/g)	5.8	7.5	4.2	5.1	6.4	8.5	4.6	5.9
Leucine (mg/g)	7.9	13.9	5.7	10.1	8.6	17.3	6.3	11.4
Valine (mg/g)	7.8	8.7	5.7	6.4	8.5	10.0	6.2	7.3
Histidine (mg/g)	2.2	4.7	1.6	3.3	2.4	4.9	1.6	3.7
Calcium (mg/g)	34.5	-	34.5	-	37.7	-	37.7	-
Available P (mg/g)	3.0	-	3.0	-	3.3	-	3.3	-
Sodium (mg/g)	1.6	-	1.6	-	1.6	-	1.6	-
Predicted Intakes								
Feed (g/day)	116	-	116	-	106	-	106	-
Lysine (mg/d)	990	-	720	-	990	-	720	-

P = Phosphorus

Calc. = Calculated during formulation

Actual = Observed from laboratory analysis

Table 2.3: *Proportions of the four basal feeds (as fed) used in blending the feeds used in the experiment and their actual lysine and energy contents*

	Feed					
	A	B	C	D		
Treatment no.	HP/LE	LP/LE	HP/HE	LP/HE	Lysine (g/kg) ♣	Energy (MJ/kg)♣♣
1	-	-	-	100.0	6.1	11.4
2	-	50.0	-	50.0	5.5	10.8
3	-	100.0	-	-	4.9	10.2
4	-	-	25.0	75.0	6.7	11.6
5	12.5	37.5	12.5	37.5	6.2	10.9
6	25.0	75.0	-	-	5.7	10.3
7	-	-	50.0	50.0	7.3	11.7
8	25.0	25.0	25.0	25.0	6.9	11.0
9	50.0	50.0	-	-	6.6	10.4
10	-	-	75.0	25.0	7.9	11.9
11	37.5	12.5	37.5	12.5	7.7	11.2
12	75.0	25.0	-	-	7.4	10.4
13	-	-	100.0	-	8.5	12.0
14	50.0	-	50.0	-	8.4	11.3
15	100.0	-	-	-	8.3	10.5

♣ Analysed (from laboratory analysis)

♣♣ Analysed AME (bioassay)

2.2.1.3 Feeding procedure

The self-feeding troughs used in this trial were designed to hold up to 1.5 kg of feed. Each bird was allocated between 1.4 and 2 kg of feed at the start of the first week and the amount was maintained by adding the feed at the start of each new week after weighing the feed remaining in the trough at the end of the week. Feed intake (g/bird d) was calculated by subtracting the remaining amount from the amount allocated at the beginning of the week and dividing by the number of days between weighing.

2.2.1.4 Measurements

Three body weights were recorded through the experimental period of ten weeks (at first day of experiment, last day of week five and last day of week ten) to determine the change in body weight.

Egg numbers were recorded daily, at the same time each day. All eggs produced on three consecutive days during each week were weighed (to determine mean egg weight). Egg output was calculated on a weekly basis by multiplying the daily rate of lay during the week by the mean egg weight for the week.

2.2.1.5 Length of the experiment

The trial ran for ten weeks (from 30 to 40 weeks of age).

2.2.1.6 Statistical analysis

The design of the experiment was a 5 x 3 factorial, completely randomised design. The means of all treatments were calculated for the last four weeks of the experimental period, on assumption that by this time the response of the birds would have stabilised on each treatment. The General Linear Model was used for the analysis of variance egg weight and egg output, while the initial body weight was used as a covariate for feed, energy, lysine intake and weight gain; and to compute the treatment means (using the statistical package GENSTAT, 1998). The initial body weight was used as a covariate to obtain the true response of energy and lysine without the effect of initial body weight. Dead birds were denoted as missing plots for analysis purposes (bird 26, 36 and 169).

2.2.2 Results

From Table 2.3 it can be seen that the lysine concentration within a lysine level was not consistent over the energy levels and similar for energy concentration over the lysine levels. The inconsistency of these two factors will be discussed later.

2.2.2.1 Rate of lay, egg weight and output

The mean responses in rate of lay, egg weight and egg output for the dietary lysine and energy contents used in this trial are given in Table 2.4. Neither the lysine nor the energy content of the feeds had a significant effect on rate of lay, egg weight or egg output when birds were at peak of production. Although there were some variation in these response variables due to dietary energy and lysine contents, they were not statistically significant.

2.2.2.2 Feed, energy, lysine intake and body weight gain

The mean responses in feed, energy, lysine intake and body weight gain to dietary lysine and energy contents are given in Table 2.5. The lysine content of the diet had no significant effect on the amount of feed consumed, but food intake was significantly ($p<0.001$) influenced by the energy content of the diet. Feed intake decreased as the energy content of the diet increased, with highest and lowest feed intakes realised at the lowest and highest energy concentrations respectively. The energy intake by the hens increased linearly with an increase in the energy content of the feed ($p<0.001$), whereas the lysine intake increased linearly with an increase in both energy ($p<0.01$) and lysine content ($p<0.001$) of the diet. The significant ($p<0.05$) interaction between dietary energy and lysine contents that affected lysine intake shows that lysine intake does not change consistently with lysine content over different energy levels.

The result indicates that dietary energy content had a significant ($p<0.001$) effect on the weight gain of the birds. This significant effect was predominantly between the lowest energy level and the other two levels, with the difference between the medium and high energy level not being statistically significant.

Table 2.4: *Effect of dietary lysine and energy content on rate of lay (%), egg weight (g) and egg output (g/bird d) of young hens*

Response variables	Lysine (g/kg)	ME (MJ/kg) 10.35	11.04	11.73	Means (Lysine)
Rate of lay (%)	5.47	93.30	95.98	95.48	94.92
	6.20	94.42	95.54	92.62	94.19
	6.92	95.09	96.21	91.52	94.27
	7.65	93.97	89.06	95.76	92.93
	8.37	97.77	96.88	95.54	96.73
	Means (ME)	94.91	94.73	94.18	
	SED: Energy = 1.51[x]		Lysine = 1.95[x]	Energy x Lysine = 3.38[x]	
Egg weight (g)	5.47	61.98	60.57	61.06	61.20
	6.20	60.97	63.41	63.01	62.46
	6.92	62.65	61.33	64.63	62.87
	7.65	62.55	61.90	65.31	63.25
	8.37	62.87	62.35	62.63	62.62
	Means (ME)	62.20	61.91	63.33	
	SED: Energy = 0.68[x]		Lysine = 0.88[x]	Energy x Lysine = 1.52[x]	
Egg output (g/bird d)	5.47	57.77	58.17	58.39	58.11
	6.20	57.50	60.35	59.13	58.99
	6.92	59.39	58.99	59.39	59.26
	7.65	58.90	55.01	62.46	58.79
	8.37	61.45	60.41	59.83	60.56
	Means (ME)	59.00	58.59	59.84	
	SED: Energy = 1.14[x]		Lysine = 1.47[x]	Energy x Lysine = 2.54[x]	

[x] P> 0.05

Table 2.5: *Effect of dietary lysine and energy content on feed intake, energy intake, lysine intake and body weight gain of young hens*

Response variables	Lysine (g/kg)	ME (MJ/kg) 10.35	11.04	11.73	Means (Lysine)
Feed intake (g/b d)	5.47	124.91	124.58	116.38	121.96
	6.20	123.14	121.01	114.92	119.69
	6.92	123.07	120.52	116.94	120.18
	7.65	124.72	117.06	114.92	118.90
	8.37	125.59	122.42	115.09	121.03
	Means (ME)	124.29	121.12	115.65	
	SED: Energy = 1.65***		Lysine = 2.13 [x]	Energy x Lysine = 3.68 [x]	
Energy intake (kJ/bird d)	5.47	1268.72	1345.44	1331.33	1315.14
	6.20	1262.84	1321.37	1331.28	1305.19
	6.92	1273.88	1330.51	1371.52	1325.32
	7.65	1302.47	1306.38	1364.39	1324.38
	8.37	1323.63	1380.76	1382.84	1362.42
	Means (ME)	1286.29	1336.91	1356.27	
	SED: Energy = 18.14***		Lysine = 23.41 [x]	Energy x Lysine = 40.55 [x]	
Lysine intake (mg/bird d)	5.47	609.63	681.17	704.24	665.03
	6.20	706.19	753.15	772.61	744.01
	6.92	810.02	842.23	864.76	839.00
	7.65	926.14	906.91	926.93	919.89
	8.37	1038.68	1040.76	1005.23	1028.34
	Means (ME)	818.11	844.92	854.66	
	SED: Energy = 11.51**		Lysine = 14.86***	Energy x Lysine = 25.73*	
Weight gain (g/bird d)	5.47	0.29	0.25	1.15	0.56
	6.20	0.05	0.66	1.52	0.74
	6.92	0.35	1.00	0.85	0.73
	7.65	0.40	1.26	1.14	0.94
	8.37	0.31	0.66	0.63	0.53
	Means (ME)	0.28	0.77	1.06	
	SED: Energy = 0.19***		Lysine = 0.25 [x]	Energy x Lysine = 0.43 [x]	

* $P< 0.05$ ** $P< 0.01$ *** $P< 0.001$ [x] $P> 0.05$

2.2.2.3 Effect of initial body weight

The mean response in rate of lay, egg weight, egg output, feed intake, feed energy intake, lysine intake, weight gain, and feed, energy and lysine intake per kg body weight for initial body weight categories are given in Table 2.6. Rate of lay, egg weight and egg output were not affected by the differences in body weight of the hens, while body weight gain was significantly ($p < 0.01$) affected by the initial body weight of the birds. The influence of initial body weight on feed intake, energy intake and lysine intake was significant ($p < 0.001$). Significant ($p < 0.05$) negative linear relationships, due to initial body weight, were observed on feed, energy and lysine intake per kg body weight.

Table 2.6: *Effect of initial body weight (kg ranges) on the response parameters of young hens*

	Body weight categories (kg)					
Response	(1.26-1.72)	(1.73-1.78)	(1.79-1.85)	(1.87-2.31)	SEM	Significance level
Rate of lay (%)	95.75	95.27	96.14	96.52	0.64	x
Egg weight (g)	61.17	62.71	62.36	63.39	0.57	x
Egg output (g/b d)	58.58	59.68	59.97	61.19	0.68	x
Feed intake (g/b d)	116.62	118.79	121.92	124.89	1.21	***
Feed intake / kg BW (g/b d)	68.00	65.57	65.68	62.00	2.52	***
ME intake (kJ/b d)	1284.54	1309.70	1344.47	1376.97	13.27	***
ME intake / kg BW (kJ/b d)	752.37	723.08	721.23	685.80	8.03	***
Lysine intake (mg/b d)	803.44	820.86	844.13	863.85	0.27	***
Lysine intake / kg BW (mg/b d)	483.55	451.04	458.81	433.43	1.17	*
Weight gain (g/b d)	0.70	0.86	0.69	0.27	0.14	**

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$ x $p > 0.05$

2.3 EXPERIMENT 2 (OLD HENS; 60 – 70 WEEKS OF AGE)

2.3.1 Materials and methods

Only material and methods different to those used in experiment one will be explained. The feeding procedure, measurements and statistical analysis were the same as in experiment 1. The length of the experiment was also 10 weeks, but older hens were used in this experiment.

2.3.1.1 Bird and management

Two hundred and forty Lohmann Brown laying hens were transferred to individual cages. These birds were from the same group as those reared in experiment 1, and had been fed commercial layer feed from the time they reached 50 % rate of lay until they were sixty weeks old. They were divided into four groups according to their body weight, as was done in the first experiment.

2.3.1.2 Treatments and feeds

Four basal feeds were formulated (two protein and two energy levels, high and low respectively) using the feed formulation program WINFEED (Table 2.7). These feeds were aimed to be close in nutrient contents to the feeds used in experiment 1. The calculated nutrient contents together with the actual are shown in Table 2.8. Instead of blending the four basal feeds as in experiment 1 a mistake was made when calculating the proportions to be blended, and instead of producing five lysine levels at three energy levels, only three lysine levels were produced, at five energy levels (Table 2.9).

Table 2.7: *The composition (g/kg as fed) of the four basal feeds used in the experiment*

	Feed			
	A	B	C	D
Ingredients	HP/LE	HP/HE	LP/LE	LP/HE
Yellow maize	340.7	459.9	326.3	603.5
Fish meal 65	0.00	0.00	8.0	0.00
Full fat soya	218.1	87.5	443.3	194.2
Maize gluten 60	80.7	0.00	60.0	40.7
Wheat bran	256.6	248.2	58.5	54.1
Limestone	91.8	91.8	88.6	90.5
Mono-calcium Phosphate	5.8	6.3	9.0	10.4
Salt	2.6	2.6	2.5	2.7
Vit + min premix (layer)	2.5	2.5	2.5	2.5
Sodium bicarbonate	1.3	1.3	1.2	1.3

Table 2.8 *Calculated and analysed nutrient contents (as fed) of the four basal feeds*

	Feeds							
	A		B		C		D	
	HP/LE		HP/HE		LP/LE		LP/LE	
Nutrients	Calc.	Actual	Calc.	Actual	Calc.	Actual	Calc.	Actual
Dry matter (%)	-	90.7	-	91.0	-	90.4	-	90.3
AME (MJ/kg)	10.5	11.7	10.5	12.8	12.0	11.3	12.0	12.3
Protein (g/kg)	202.1	201.2	244.9	252.5	149.2	147.2	159.8	145.3
Lysine (mg/g)	8.6	7.4	7.2	10.9	12.9	5.7	7.0	5.3
Arginine (mg/g)	11.8	11.0	9.7	14.2	15.7	6.0	9.2	7.9
Isoleucine (mg/g)	8.6	7.8	6.2	10.7	11.3	5.0	6.9	5.7
Methionine (mg/g)	3.6	2.4	2.4	2.9	4.1	1.5	2.9	1.9
Phenyalanine (mg/g)	10.4	9.9	7.1	11.3	12.8	5.0	8.3	6.7
Threonine (mg/g)	7.3	6.1	5.5	8.0	9.4	4.6	5.9	4.5
Valine (mg/g)	9.9	10.2	7.4	11.2	12.1	6.3	7.9	6.3
Calcium (mg/g)	35.0	-	35.0	-	35.0	-	35.0	-
Available P (mg/g)	3.5	-	3.5	-	3.5	-	3.5	-
Sodium (mg/g)	1.8	-	1.8	-	1.8	-	1.8	-
Chloride (mg/g)	2.0	-	2.0	-	2.0	-	2.0	-
Predicted Intake								
Feed intake (g/b d)	118	-	118	-	106	-	106	-
Lysine Intake (mg/b d)	1003	-	732	-	996	-	721	-

The feed and lysine intake were calculated when egg output and body weight were 58 g/d and 1.8 kg respectively.

P = Phosphorus

Calc. = Calculated during formulation

Actual = Observed (from laboratory analysis)

Table 2.9: *Proportions of the four basal feeds (as fed) used in blending the feeds used in the experiment and the analysed lysine and energy contents*

	Feed					
	A	B	C	D		
Treatment no.	HP/LE	HP/HE	LP/LE	LP/HE	Lysine (g/kg) ♣	Energy (MJ/kg) ♣♣
1	-	-	-	100.00	5.31	12.25
2	-	50.00	-	50.00	8.10	12.54
3	-	100.00	-	-	10.88	12.83
4	-	-	25.00	75.00	5.41	12.01
5	12.50	37.50	12.50	37.50	7.72	12.28
6	25.00	75.00	-	-	10.01	12.55
7	-	-	50.00	50.00	5.51	11.76
8	25.00	25.00	25.00	25.00	7.33	12.02
9	50.00	50.00	-	-	9.14	12.27
10	-	-	75.00	25.00	5.61	11.51
11	37.50	12.50	37.50	12.50	6.94	11.75
12	75.00	25.00	-	-	8.27	11.98
13	-	-	100.00	-	5.71	11.27
14	50.00	-	50.00	-	6.55	11.49
15	100.00	-	-	-	7.39	11.70

♣ Analysed (from laboratory analysis)

♣♣ Analysed AME (bioassay)

2.3.2 Results

2.3.2.1 Rate of lay, egg weight and egg output

The mean responses in rate of lay, egg weight and egg output, for the dietary treatments containing different dietary lysine and energy contents used in this trial, are given in Table 2.10. Neither the lysine nor the energy content of the feed had a significant effect on rate of lay, egg weight or egg output for birds in the late production period.

2.3.2.2 Feed, energy, lysine intake and body weight change

The mean responses in feed, energy, lysine intake and change in body weight for dietary lysine and energy contents are given in Table 2.11. The results show significant ($p<0.05$) effects of both dietary lysine and energy content on the amount of feed consumed. The consumption of energy by old laying hens was significantly ($p<0.05$) influenced by the dietary lysine content. There was a significant difference in energy intake between the lowest dietary lysine content and the other lysine levels (medium and high). The highest energy intake (1318.41 kJ/bird d) was attained at the medium dietary lysine. There was a significant ($p<0.001$) effect of energy, lysine concentration and energy by lysine interaction on lysine intake during the later laying period. Although dietary energy content of the feed had a significant effect on lysine intake, no specific trend was observed.

Body weight gain was significantly affected by both dietary lysine ($p<0.01$) and energy ($p<0.05$) during the late laying period. The result showed that old laying hens on the lowest dietary lysine content lost more weight than hens on the higher levels of dietary lysine, and that difference was significant, but the weight loss between the higher contents (medium and high) were more or less the same. A linear relationship was observed between the dietary energy content and body weight gain. Old laying hens lost less body weight as dietary energy contents increased.

Table 2.10: *Effect of dietary lysine and energy content on rate of lay (%), egg weight (g) and egg output (g/bird d) of old laying hens*

Response variables	ME (MJ/kg)	Lysine (g/kg) 5.51	7.32	9.14	Means (ME)
Rate of lay (%)	11.48	55.13	63.87	64.45	61.23
	11.75	58.21	78.39	75.21	70.56
	12.01	48.89	72.33	63.24	61.48
	12.28	78.12	69.56	60.52	69.44
	12.54	67.04	60.28	64.03	63.82
	Means (Lysine)	61.37	68.92	65.52	
	SED: Energy = 6.82 ^{x}		Lysine = 4.86 ^{x}		Energy x Lysine = 0.88 ^{x}
Egg weight (g)	11.48	54.60	60.39	58.51	57.83
	11.75	55.96	63.67	65.53	61.72
	12.01	54.52	63.57	60.39	59.49
	12.28	62.59	62.38	60.85	61.94
	12.54	62.77	55.30	59.89	59.32
	Means (Lysine)	58.09	61.06	61.03	
	SED: Energy = 2.97 ^{x}		Lysine = 2.30 ^{x}		Energy x Lysine = 5.14 ^{x}
Egg output (g/bird d)	11.48	33.84	41.63	42.62	39.34
	11.75	37.01	51.66	50.07	46.28
	12.01	31.28	49.09	42.94	41.12
	12.28	49.32	46.71	41.53	45.76
	12.54	43.23	39.78	44.09	42.43
	Means (Lysine)	38.87	45.84	44.16	
	SED: Energy = 4.17 ^{x}		Lysine = 3.23 ^{x}		Energy x Lysine = 7.22 ^{x}

^{x} P> 0.05

Table 2.11: *Effect of dietary lysine and energy content on feed intake, energy intake, lysine intake and body weight gain of old laying hens*

Response variables	ME (MJ/kg)	Lysine (g/kg) 5.51	7.32	9.14	Means (ME)
Feed intake (g/bird d)	11.48	100.22	115.37	110.30	108.63
	11.75	105.13	114.78	111.36	110.42
	12.01	101.72	109.71	102.18	104.54
	12.28	108.83	107.05	103.33	106.40
	12.54	103.61	102.48	97.14	101.08
	Means (Lysine)	103.90	109.88	104.86	
	SED: Energy = 2.99*		Lysine = 2.32*	Energy x Lysine = 5.18 [x]	
Energy intake (kJ/bird d)	11.48	1128.73	1324.85	1291.35	1248.05
	11.75	1210.06	1349.02	1333.87	1297.96
	12.01	1195.91	1318.14	1253.26	1256.29
	12.28	1306.68	1314.25	1296.95	1306.34
	12.54	1268.87	1286.39	1246.38	1267.19
	Means (Lysine)	1221.86	1318.41	1284.43	
	SED: Energy = 35.76 [x]		Lysine = 27.74*	Energy x Lysine = 62.05 [x]	
Lysine intake (mg/bird d)	11.48	571.89	755.16	815.13	714.14
	11.75	589.14	796.27	919.87	768.41
	12.01	560.76	803.23	931.59	765.18
	12.28	585.68	824.81	1034.21	814.92
	12.54	551.04	830.29	1057.76	813.03
	Means (Lysine)	571.65	801.92	951.67	
	SED: Energy = 21.83***		Lysine = 16.91***	Energy x Lysine = 37.82***	
Weight gain (g/bird d)	11.48	-0.17	-0.09	-0.07	-0.11
	11.75	-0.15	-0.02	-0.11	-0.10
	12.01	-0.12	-0.06	-0.05	-0.08
	12.28	-0.06	-0.05	-0.02	-0.04
	12.54	-0.10	0.04	-0.01	-0.02
	Means (Lysine)	-0.12	-0.04	-0.05	
	SED: Energy = 0.03*		Lysine = 0.02**	Energy x Lysine = 0.05 [x]	

* P< 0.05   ** P< 0.01   *** P< 0.001   [x] P> 0.05

2.3.2.3 Effect of initial body weight

The mean response in rate of lay, egg weight, egg output, feed intake, feed energy intake, lysine intake, weight gain, and feed, energy and lysine intake per kg body weight for initial body weight categories are given in 2.12. Rate of lay, egg weight and egg output were not significantly influenced by the initial body weight of the birds. Initial body weight had a significant effect on feed ($p<0.001$), energy ($p<0.001$) and lysine intake ($p<0.05$) in these hens. Feed and energy intake increased with increasing initial body weight up to the third body weight category and thereafter they remained more or less the same. Lysine intake followed the feed and energy intake relationships with initial body weight, but instead of remaining constant for the third and fourth body weight category, it was lower in the fourth category. There was a significant ($p<0.001$) relationship between body weight gain and initial body weight. The result showed that lighter hens lost less body weight as compared to heavier hens during this experiment. Significant ($p< 0.01$) negative linear relationships, due to initial body weight, were observed on feed, energy and lysine intake per kg body weight.

Table 2.12: *Effect of initial body weights (kg ranges) on the response variables of old hens*

	Body weights categories					
Response	(1.29 – 1.79)	(1.80 – 1.90)	(1.91 – 2.03)	(2.04 – 2.95)	SEM	Significant level
Rate of lay (%)	58.51	63.04	73.25	66.85	3.98	x
Egg weight (g)	59.45	57.39	64.11	59.56	1.86	x
Egg output (g/b d)	38.05	41.26	49.00	44.01	2.66	x
Feed intake (g/b d)	99.85	104.79	109.98	110.38	1.95	***
Feed intake / kg BW (g/b d)	60.55	59.86	59.70	55.28	0.37	**
ME intake (kJ/b d)	1196.73	1261.46	1320.90	1322.17	23.35	***
ME intake / kg BW (kJ/b d)	725.73	719.96	716.44	661.63	9.81	***
Lysine intake (mg/b d)	711.09	796.41	825.99	766.25	24.96	*
Lysine intake / kg BW (mg/b d)	431.00	452.23	445.68	382.24	10.02	***
Weight gain (g/b d)	-0.01	-0.05	-0.09	-0.13	0.02	***

* P< 0.05 ** P< 0.01 *** P< 0.001 x P>0.05

2.4 DISCUSSION

Different strains of laying hens were used in the research conducted by Brown *et al.* (1965) to test the effect of dietary energy concentration on laying performance. They found that egg production was not affected by any dietary treatments other than the higher energy diet containing a low (13 %) protein content. Egg production for that particular treatment was significantly lower ($p < 0.001$). In the present study no significant differences were obtained in rate of lay, egg weight and egg output due to dietary energy concentration (in both experiments). The results agree with the research by Gous *et al.* (1987) that showed that dietary energy concentration does not have an effect on rate of lay.

Significant effects of lysine concentration of the diet were observed by Gous *et al.* (1987) on rate of lay and egg weight. In the experiment conducted by Brown *et al.* (1965) it was observed that small eggs and low rate of lay were associated with a low protein diet, which shows that rate of lay and egg weight are affected by protein content of the diet. But in the present experiments the lowest dietary lysine content was designed to be only marginally deficient, thereby allowing the hens to perform adequately if they could increase intake of this food sufficiently to meet their daily lysine requirements for maintenance and egg production. The effect of dietary lysine and energy contents had no significant effects on egg weight and egg output. Although the means for various combinations were different, the standard errors of treatment means were too high to allow statistically significant differences to be realised.

In the past it was generally accepted that feed intake by poultry is governed, under most conditions by the dietary caloric density (Hill and Dansky, 1954). Brown *et al.* (1965) found that pullets on medium energy diet consumed 0.14 percent more feed than those on high energy diet. In all three experiments conducted by Gous *et al.* (1987) it was found that at all energy concentrations the diet containing the lowest protein content was associated with significantly reduced food intake. In the present study it was found that the difference in feed intake by birds on feed differing by 0.69 MJ ME/kg was 4 g/bird d for the first experiment and it was highly significant ($p<0.001$). For the second experiment both dietary lysine and energy contents had a significant effect ($p<0.05$) on feed intake, but that was due to the blending mistake that led to unexpected trends.

Highest feed intake was realised at the lowest lysine content (marginally deficient) in the first experiment, although it was not statistically significant from the other levels. The effect of dietary protein content noted by Gous *et al.* (1987), was because three of the five feeds were below the requirement, all of which would have been expected to severely influence the feed intake.

The amount of energy that a bird will consume was shown not to be constant over all dietary energy concentrations, being lower at low dietary energy levels and higher at high dietary energy concentration (Gous *et al.*, 1987). It was also observed by Morris (1968) that birds consume less energy as the energy concentrations of the diet is reduced and over-consume it as the dietary energy concentration is increased. There have been some reports indicating that growing and laying hens maintain constant energy intake when diets of widely differing energy concentrations are given (Hill, 1962; as cited by Morris, 1968). That seems to be incorrect, since the reduction in feed intake that occurs at high dietary energy concentration is generally insufficient to maintain constant energy consumption and so energy intake tended to be greater at higher dietary energy concentration (Morris, 1968). The effect of energy concentration on energy intake was significant in the first experiment ($p<0.001$) and in the second ($p<0.05$). These results confirm that energy intake increases when energy concentration of the diet is increasing (Morris, 1968; and Gous *et al.*, 1987).

Lysine intake was observed to be increasing linearly with both an increase in dietary energy ($p<0.01$) and lysine content ($p<0.001$) of the diet in the first experiment. The difference in lysine intake by the young hens on feeds differing by 0.72 g lysine/kg was 90.75 mg/bird d. Significant effects of both dietary energy and lysine contents ($p<0.001$) on lysine intake were observed in the second experiment. Lysine intake was increasing with increasing dietary lysine content, but no trend was observed for energy content. The difference in lysine intake of older hens on feeds differing by 1.81 g lysine/kg was 190.01 mg/bird d. The effect of dietary energy on lysine intake was brought about by the lysine contents being inconsistent within a lysine level. Lysine content was increasing linearly within a lysine and that led to an increase in lysine intake when energy content of the diet was increasing (in the first experiment), therefore the contents of lysine and energy in the treatments were confounded.

Shapiro and Fisher (1965) found that at all levels of dietary protein hens gained weight as an indication of excessive intake of dietary energy. Gous *et al.* (1987) showed that body weight gain is positively correlated to energy concentration of the diet: as the energy concentration of the diet increases, birds tend to gain more weight. Although the analysis of weight gain showed no significant differences between energy levels, it was evident at the end of the trial that birds grew more when receiving diets with high energy concentrations (Griessel, 1980). The results of the present study agree with those by the previous researchers, showing a significant effect of dietary energy concentration on body weight gains, with $p < 0.001$ and $p < 0.01$ for the first and second experiment respectively. Hens in the first experiment gained weight and lost less weight in the second experiment as the energy content of the diet increased. Weight loss that occurred in the second experiment was due to low feed intake that was observed. This indicates that the hens were possibly consuming more energy on the high energy feeds than they needed to in order to be laying at their potential.

The effect of initial body weight was considered in all response variables. Initial body weight had no significant effect on rate of lay, egg weight or egg output, as was expected. Feed, energy and lysine intake were highly significantly ($p<0.001$) affected by the initial body weight of the hens in experiment one, but the effect on lysine intake in the second experiment was less, yet significant ($p< 0.05$). Therefore the true effects of energy and lysine on those response variables were computed by using initial body weight as a covariate. The use of initial body weight as a covariate reduced the error variance by 7.56, 6.00 and 1.14% in the first, and 6.97, 6.97 and 1.21 % in the second experiment for feed, energy and lysine intake respectively. There was a positive linear correlation of 0.28, 0.25 and 0.12 in the first, and 0.26, 0.26 and 0.11 in the second experiment between feed, energy and lysine intake respectively, with the initial body weight. The higher the initial body weight the more feed the hen consumed. As a result of increasing food intake with increasing initial body weight, energy and lysine intake also increases. This implies that, given a feed of specific lysine and energy concentration; feed, energy and lysine intake will increase with increase in initial body weight. The results for feed, energy and lysine intake per initial body weight (Tables 2.6 and 2.12) shows that the amount of feed, energy and lysine available for egg production decreased when the initial body weight increased. That was statistical significant only between the highest and the other body weigh categories ($P<0.01$). The increase in the amount of feed, energy and lysine consumed with increasing initial body weight is a function of an increase in the amount of energy and lysine required to maintain the increasing grams of body weight, but the amount of energy and lysine required for egg production remains relatively constant.

From the results of the present study and previous research conducted, it may be concluded that dietary energy content has no significant effect on egg production (rate of lay, egg weight and egg output). Dietary lysine content had no effect on egg production because all lysine contents were sufficient to support maximum egg production, but in previous studies where amino acid content was limiting, their effect was significant.

The amount of the feed and energy that the birds consume depends primarily on the dietary energy content of that particular feed, being high at low and low at high dietary energy content respectively, for feed intake; while energy intake increased positively with increasing dietary energy content. Lysine intake depends directly on the dietary lysine content and indirectly on dietary energy content, since the latter affects feed intake. Young laying pullets gained weight while older hens lost less weight, as the dietary energy content increased. Hens tend to lose weight as their initial body weight gets higher at a given dietary lysine and energy content. Weight loss observed with old hens may have been associated with low feed intake observed.

CHAPTER 3

ECONOMIC ANALYSIS

3.1 INTRODUCTION

The profitability of a commercial egg production enterprise is affected by many factors, two of which can be control. These are feed cost and the quality of the product produced. Feed costs account for between 70 and 80 % of the total production cost (in both meat and egg production). The extent by which a poultry manager can reduce his or her feed cost will have a direct effect on the profitability of the farm.

The quantity of the feed that birds will consume depends indirectly on the dietary energy content of that particular feed (Morris, 1968) and therefore the amino acid intake will also indirectly depend on it (Gous et al., 1987). By manipulating dietary energy content, feed intake and, therefore, feed costs and productivity on the farm can be controlled. Feed cost *per se* is not a problem, but rather is to achieve the product value that can justify the feed costs. When the value of the product produced is less than the value of the feed used the farm business heads towards an insolvent state. It is an objective of all farm business to produce a product of high value in order to cover the feed plus other production costs.

Not all combinations of dietary energy and amino acids will yield the same egg production and income; and even if they do, their feed costs would be different. Therefore it is important for the farm manager to determine which combinations will result in profit maximization. It is understandable that broiler meat prices may fluctuate due to other forces (like fluctuation in beef and mutton) but the egg price does not usually fluctuate, therefore it is easy to influence profitability through manipulation of feed costs.

The objective of this economic analysis was to determine whether the combinations of dietary lysine and energy that produces the maximum margin over food cost (under different egg prices) in the early period of lay would change when the birds were older and production had declined.

3.2 YOUNG HENS (30 – 40 WEEKS OF AGE)

3.2.1 Materials and methods

General linear regressions were fitted to the data obtained from the previous chapter, to describe the effects of lysine and energy contents on the variables contributing to profit, i.e. food intake, egg weight and rate of lay. The expected feed intakes, egg weights and rate of lay for different treatments (dietary lysine and energy combinations) were then calculated from these regression equations, which are presented below.

Feed intake (FI; g/bird d), with R^2 and SE of 10.1 and 9.53 respectively

FI (E1) = 125.30 – 1.150 lysine

FI (E2) = 122.22 – 0.2 lysine

FI (E3) = 114.46 + 0.3 lysine

Egg weight (EW; g), with R^2 and SE of 2.4 and 4.32 respectively

EW (E1) = 60.84 + 0.508 lysine

EW (E2) = 61.11 + 0.228 lysine

EW (E3) = 61.72 + 0.481 lysine

Rate of lay (ROL; %), with R^2 and SE of 1.1 and 5.39 respectively

ROL (E1) = 93.17 + 0.823 lysine

ROL (E2) = 96.11 + 0.048 lysine

ROL (E3) = 93.93 + 0.565 lysine

Where E1, E2 and E3 = low, medium and high dietary energy contents respectively, and lysine = dietary lysine content (g/kg).

Expected mean responses in feed intake, egg weight and rate of lay for dietary lysine and energy contents are given in Table 3.1. Feeding costs were calculated by multiplying the ingredients prices (Table 3.2) with their inclusion rates (Table 2.1) for each combination (treatment), and then multiplying this by the amount of feed consumed (Table 3.1) in that particular combination. A table of proportions of egg grades (small, medium, large, extra large and jumbo) for each mean egg weight was developed, on the basis of an 8 % coefficient of variation of egg weight, assuming that the distribution was normal (Appendix 1). The price for a dozen large eggs from

Ukulinga Research Farm was used (R3.14 per dozen), assuming that it was close to the price used by commercial farms and the price for other grades were calculated by using -30, -15, 15 and 30 % change in large eggs price for small, medium, extra large and jumbo respectively. Table 3.3 gives egg prices (c/egg) for different grades under normal, increase and decrease by 15 % in price for all grades. Incomes generated by specific combinations were calculated using the V-lookup function in Excel (Harvey, 1995). Income per 100 hens was calculated by multiplying income per hen with the rate of lay for that treatment (Table 3.1).

Table 3.1: *Expected means for feed intake (g/bird d), egg weight (g) and rate of lay (%) of young hens as influenced by dietary lysine and energy content*

Response variables	Lysine (g/kg)	ME (MJ/kg)		
		10.35	11.04	11.73
Expected feed intake (g/bird d)	5.47	124.5	121.1	116.1
	6.20	124.4	121.0	116.3
	6.92	124.3	120.8	116.5
	7.65	124.2	120.7	116.8
	8.37	124.0	120.6	117.0
Expected egg weight (g)	5.47	63.62	62.36	64.35
	6.20	63.99	62.52	64.70
	6.92	64.36	62.69	65.05
	7.65	64.73	63.85	65.40
	8.37	65.09	63.02	65.75
Expected rate of lay (%)	5.47	97.67	96.54	97.02
	6.20	98.27	96.58	97.43
	6.92	98.87	96.61	97.84
	7.65	99.47	96.65	98.25
	8.37	100.06	96.68	98.66

Table 3.2: *Prices for different ingredients used for calculating feed costs*

Ingredients	Quantity (kg or l)	Price (R)	Price (R/kg or l)
Yellow maize	50.00	54.44	1.09
Fish meal 65	50.00	258.78	5.18
Soya oil cake 47	50.00	157.19	3.14
Full fat Soya	40.00	142.53	3.56
Sunflower oil cake	50.00	96.51	1.93
Maize gluten 60	50.00	179.94	3.60
Hominy chop	40.00	35.18	0.88
Wheat bran	30.00	29.74	0.99
L-lysine	1.00	26.43	26.43
DL-methionine	1.00	39.98	39.98
Sunflower oil	5.00	32.01	6.40
Limestone	1.00	0.52	0.52
Mono-Calcium Phospate	1.00	4.35	4.35
Sea salt (clean)	50.00	24.32	0.49
Choline chloride	1.00	11.43	11.40
Vit + Min Premix (layer)	2.50	40.26	16.10
Sodium bicarbonate	25	75.25	3.01

Table 3.3: *Prices for different egg grades under normal, and 15 % decrease or increase in egg price*

			Price (c/egg)		
Egg grade	Weight Range (g)	Relative price increase (%)**	Normal	- 15 %	+ 15 %
Small	< 43	-30	0.1817	0.1544	0.2090
Medium	43 - 50	-15	0.2217	0.1884	0.2550
Large*	50 - 60	0	0.2617	0.2224	0.3010
Extra large	60 - 65	15	0.3017	0.2564	0.3470
Jumbo	> 65	30	0.3417	0.2904	0.3930

* Normal egg price assumed to be R3.14 per dozen of large eggs

* * Approximate price change relative to the price of large eggs

3.2.2 Results

The feeding costs for combinations of dietary lysine and energy contents are given in Table 3.4. Feeding costs showed a positive a positive linear relationship with both dietary lysine and energy contents. The differences in costs with changing combinations of dietary lysine and energy are illustrated in Figure 3.1.

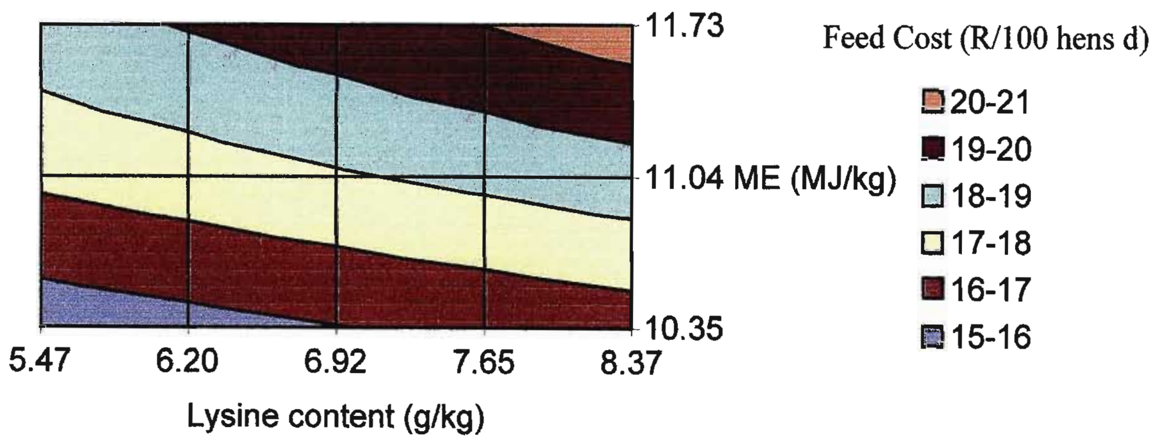

Figure 3.1: *Feed cost (R/100 hens d) for different combinations of dietary lysine and energy, for young hens.*

Table 3.4: *Calculated feeding costs (R/100 hens d) under different dietary treatments for young hens*

	ME (MJ/kg)		
Lysine (g/kg)	10.35	11.04	11.73
5.47	15.44	17.21	18.60
6.20	15.70	17.55	19.07
6.92	15.97	17.90	19.54
7.65	16.23	18.24	20.02
8.37	16.49	18.58	20.50

Table 3.5 gives the incomes for dietary lysine and energy combinations under normal, 15 % reduction and increase in egg price for all grades, and 15 % increase in price for extra large and jumbo eggs only. Under all circumstances income was positively related to the dietary lysine content, but the relationship between income and dietary energy content was more complex. Figure 3.2 illustrate the trends in income for dietary lysine and energy combinations under normal egg price.

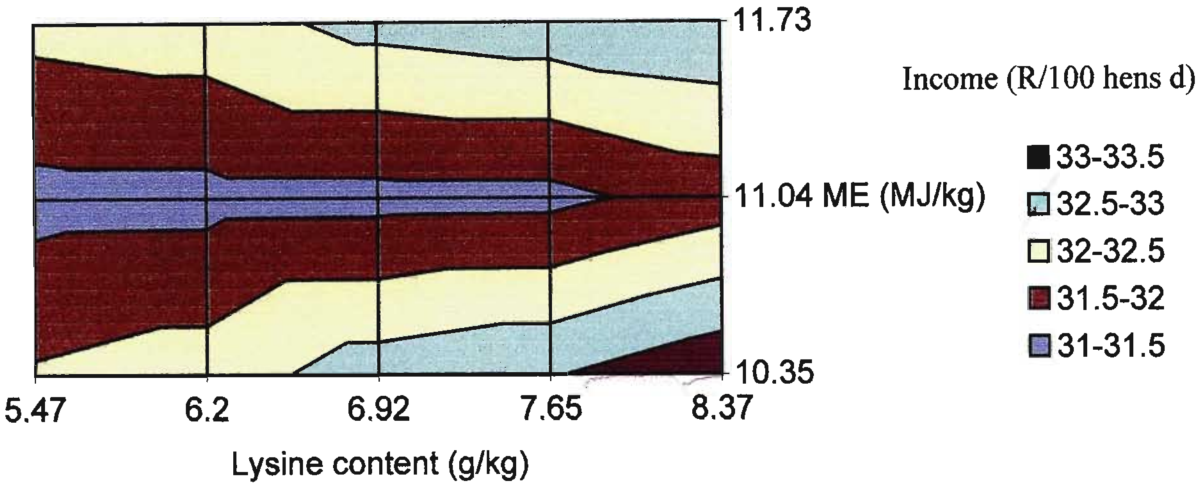

Figure 3.2: *Income (R/100 hens d) for different combinations of dietary lysine and energy under the normal egg price, for young hens.*

Table 3.6 gives the derived profit (income minus feeding cost) for dietary lysine and energy combinations under normal, 15 % reduction and increase in egg price for all grades, and 15 % increase in price for extra large and jumbo eggs only. Under all circumstance the highest profit was obtained on the diets with lowest energy and all lysine contents. The lowest profit was realized with highest dietary energy and two highest lysine contents under normal and 15 % reduction in egg price, as illustrated in Figure 3.3. At 15 % increase in egg price, lowest profit was obtained with both medium and high energy, and the same lysine contents observed under normal price (Figure 3.4). When the egg price was increased by 15 % for only extra large and jumbo eggs lowest profit was obtained with high dietary energy and all dietary lysine except the one with lowest content, and medium energy and all lysine contents except the first two with low contents. The effect of 15 % increase in price for extra large and jumbo eggs on profit generated is illustrated in Figure 3.5.

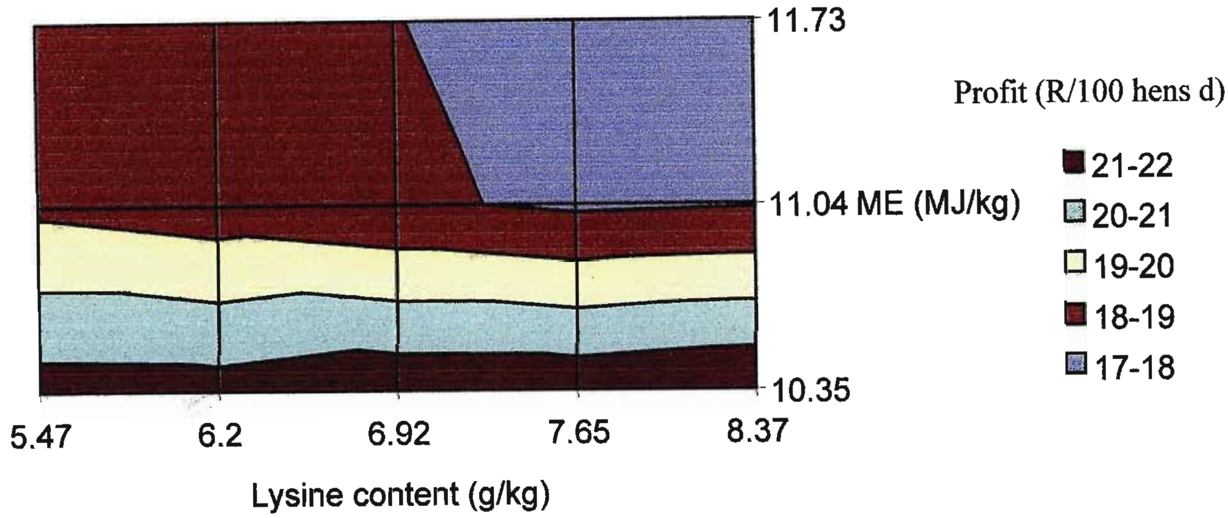

Figure 3.3: *Profit (R/100 hens d) for different combinations of dietary lysine and energy under the normal egg price, for young hens.*

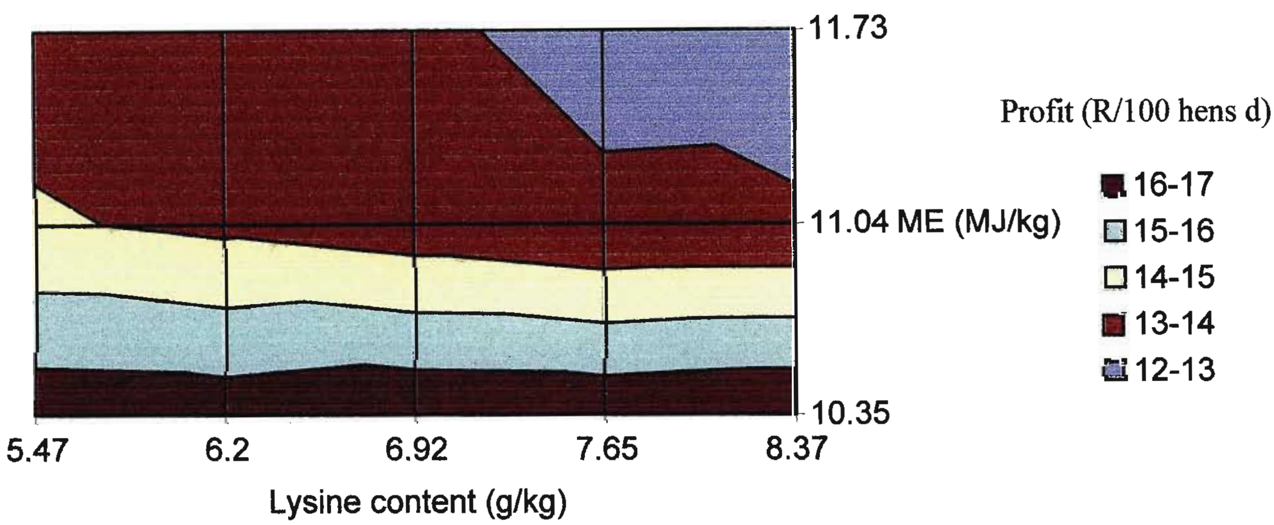

Figure 3.4: *Profit (R/100 hens d) for different combinations of dietary lysine and energy under 15 % increase in the egg price, for young hens.*

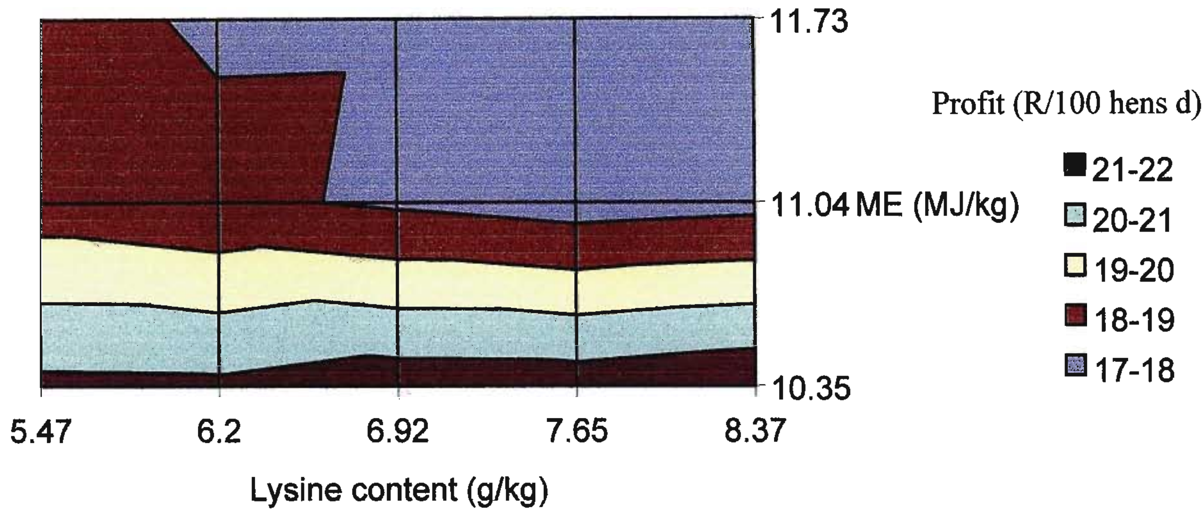

Figure 3.5: *Profit (R/100 hens d) for different combinations of dietary lysine and energy under 15 % increase for extra large and jumbo egg prices, for young hens.*

Table 3.5: *Calculated income (R/100 hens d) under different dietary treatments for young hens at normal, 15 % reduction and increase in price for all grades, and 15 % increase only for X-large and Jumbo*

		ME (MJ/kg)		
Price situation	Lysine (g/kg)	10.35	11.04	11.73
Normal egg price	5.47	32.06	31.33	32.15
	6.20	32.25	31.34	32.28
	6.92	32.76	31.35	32.66
	7.65	32.96	31.36	32.80
	8.37	33.40	31.73	32.93
15 % reduction for all grades	5.47	27.24	26.62	27.32
	6.20	27.41	26.63	27.44
	6.92	27.84	26.64	27.76
	7.65	28.01	26.65	27.87
	8.37	28.39	26.97	27.99
15 % increase for all grades	5.47	36.87	36.03	36.97
	6.20	37.10	36.05	37.13
	6.92	37.68	36.06	37.56
	7.65	37.91	36.07	37.72
	8.37	38.42	36.50	37.88
15 % increase for X-large and Jumbo	5.47	36.66	35.74	36.83
	6.20	36.88	35.75	36.98
	6.92	37.53	35.76	37.46
	7.65	37.76	35.78	37.62
	8.37	38.31	36.29	37.78

Table 3.6: *Calculated profit (R/100 hens d) under different dietary treatments for young hens at normal, 15 % reduction and increase in price for all grades, and 15 % increase only for X-large and Jumbo*

		ME (MJ/kg)		
Price situation	Lysine (g/kg)	10.35	11.04	11.73
Normal egg price	5.47	16.62	14.12	13.55
	6.20	16.55	13.79	13.21
	6.92	16.79	13.45	13.12
	7.65	16.73	13.13	12.78
	8.37	16.91	13.15	12.44
15 % reduction for all grades	5.47	11.81	9.41	8.72
	6.20	11.71	9.08	8.37
	6.92	11.87	8.75	8.21
	7.65	11.78	8.42	7.85
	8.37	11.89	8.39	7.49
15 % increase for all grades	5.47	21.43	18.82	18.38
	6.20	21.39	18.49	18.06
	6.92	21.71	18.16	18.02
	7.65	21.68	17.83	17.70
	8.37	21.92	17.92	17.38
15 % increase for X-large and Jumbo	5.47	21.22	18.52	18.23
	6.20	21.18	18.20	17.91
	6.92	21.56	17.86	17.92
	7.65	21.52	17.54	17.60
	8.37	21.82	17.71	17.28

3.3 OLD HENS (60 – 70 WEEKS OF AGE)

3.3.1 Materials and Methods

The blending error that had occurred on the second experiment resulted in dietary lysine and energy contents that were not comparable to those of the first experiment. Therefore the regression approach used to predict responses in feed intake, egg weight and rate of lay (in the first experiment) could not be used. The following theoretical assumptions (based on Lohmann Brown performance graph) were applied to the responses of young hens to get expected means (given in Table 3.7) for old hens, for economic comparison:

1. Feed intake. Although mean feed intake of older hens (60-70 weeks) in this experiment was 106.21 g/bird d, in most commercial operations birds of this age consume more feed than this. The assumption used in this economic analysis is that feed intake of older hens was 5 g greater than that of young laying hens.
2. Egg weight. Although egg weight in this period was lower than in the earlier period, it is known that egg weight increases when hen age is increasing. The assumption used in this analysis is that egg weight was 5.8 g heavier for old hens.
3. Rate of lay. The rate of lay observed was lower than what was expected at this period and therefore the assumption used is that rate of lay was 17.5 % lower for old hens.

Table 3.7: *Expected means for feed intake (g/bird d), egg weight (g) and rate of lay (%) of old laying hens as influenced by dietary lysine and energy content*

Response Variables	Lysine (g/kg)	ME (MJ/kg)		
		10.35	11.04	11.73
Expected feed intake (g/bird d)	5.47	129.47	126.13	121.10
	6.20	129.37	125.98	121.32
	6.92	129.26	125.84	121.54
	7.65	129.15	125.69	121.76
	8.37	129.04	125.55	121.97
Expected egg weight (g)	5.47	69.43	68.16	70.15
	6.20	69.79	68.32	70.51
	6.92	70.16	68.49	70.85
	7.65	70.53	69.65	71.20
	8.37	70.89	68.82	71.55
Expected rate of lay (%)	5.47	80.17	78.94	79.52
	6.20	80.77	79.08	79.93
	6.92	81.37	79.11	80.34
	7.65	81.97	79.15	80.75
	8.37	82.56	79.18	81.16

3.3.2 Results

Feeding costs for combinations of dietary lysine and energy contents are given in Table 3.8. Similar responses to those of the first experiment were observed between feeding costs with both dietary lysine and energy content (Figure 3.1).

Table 3.8: *Calculated feed costs (R/100 hens d) under different dietary treatments for old hens*

	ME (MJ/kg)		
Lysine (g/kg	10.35	11.04	11.73
5.47	16.06	17.92	19.40
6.20	16.34	18.28	19.89
6.92	16.61	18.64	20.38
7.65	16.89	18.99	20.88
8.37	17.16	19.35	21.37

Tables 3.9 gives the incomes for dietary lysine and energy combinations under normal, 15 % reduction and increase in egg price for all grades, and 15 % increase in price for extra-large and jumbo eggs only. Income was positively related to the dietary lysine content, while on the other hand income was high on both low and high dietary energy contents, but low on medium. The highest income was obtained with the combination of highest dietary lysine and low energy contents under all circumstances. Lowest income was obtained with medium energy irrespective of dietary lysine content and price adjustments. Figure 2.6 illustrate the trends of income for dietary lysine and energy combinations under 15 % increase in price for eggs of all grades.

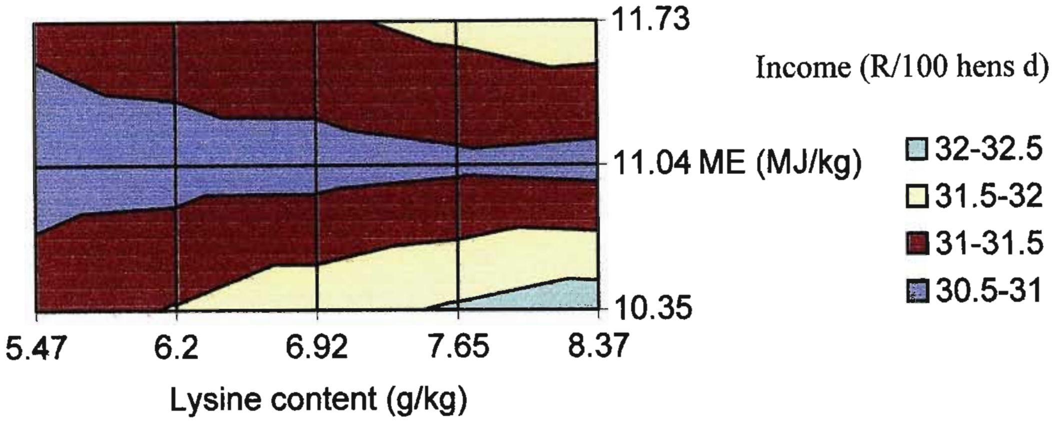

Figure 3.6: *Income (R/100 hens d) for different combinations of dietary lysine and energy with a 15 % increase in egg price for all egg grades of old hens.*

Profit generated by different combinations of dietary lysine and energy under normal egg price, 15 % reduction and increase in egg price, and 15 % increase in price for extra-large and jumbo eggs only are given in Table 3.10. Under all circumstances highest profit was obtained on low dietary energy irrespective of dietary lysine content. Lowest profit was obtained on the combination of high dietary energy and all lysine contents except the lowest. Figure 3.7 gives an illustration of the trends in profit generated under normal egg price.

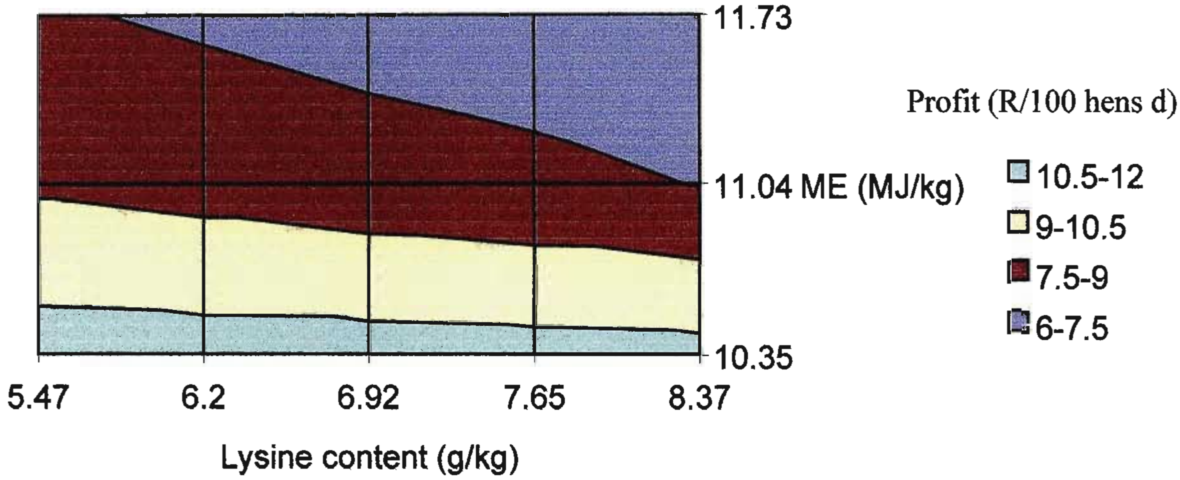

Figure 3.7: *Profit (R/100 hens d) for different combinations of dietary lysine and energy under normal egg price for old hens.*

Table 3.9: *Calculated income (R/100 hens d) under different dietary treatments for old laying hens at normal, 15 % reduction and increase in price for all grades, and 15 % increase only for X-large and Jumbo*

		ME (MJ/kg)		
Price situation	Lysine (g/kg)	10.35	11.04	11.73
Normal egg price	5.47	27.21	26.72	27.04
	6.20	27.42	26.77	27.18
	6.92	27.67	26.78	27.32
	7.65	27.87	26.87	27.50
	8.37	28.08	26.81	27.64
15 % reduction for all grades	5.47	23.13	22.71	22.98
	6.20	23.30	22.75	23.10
	6.92	23.52	22.76	23.22
	7.65	23.69	22.83	23.37
	8.37	23.86	22.78	23.49
15 % increase for all grades	5.47	31.30	30.74	31.10
	6.20	31.53	30.79	31.26
	6.92	31.82	30.80	31.42
	7.65	32.06	30.90	31.63
	8.37	32.29	30.83	31.79
15 % increase for X-large and Jumbo	5.47	31.28	30.71	31.09
	6.20	31.52	30.77	31.25
	6.92	31.81	30.78	31.41
	7.65	32.05	30.89	31.62
	8.37	32.28	30.81	31.78

Table 3.10: *Calculated profit (R/100 hens d) under different dietary treatments for old laying hens at normal, 15 % reduction and increase in price for all grades, and 15 % increase only for X-large and Jumbo*

		ME (MJ/kg)		
Price situation	Lysine (g/kg)	10.35	11.04	11.73
Normal egg price	5.47	11.16	8.80	7.65
	6.20	11.08	8.49	7.29
	6.92	11.06	8.14	6.94
	7.65	10.99	7.88	6.62
	8.37	10.92	7.46	6.27
15 % reduction for all grades	5.47	7.07	4.79	3.59
	6.20	6.97	4.47	3.21
	6.92	6.91	4.12	2.84
	7.65	6.80	3.84	2.49
	8.37	6.70	3.43	2.12
15 % increase for all grades	5.47	15.24	12.18	11.71
	6.20	15.20	12.51	11.37
	6.92	15.21	12.17	11.04
	7.65	15.17	11.91	10.75
	8.37	15.13	11.48	10.42
15 % increase for X-large and Jumbo	5.47	15.23	12.79	11.69
	6.20	15.18	12.49	11.36
	6.92	15.20	12.14	11.03
	7.65	15.16	11.89	10.75
	8.37	15.12	11.46	10.41

3.4 DISCUSSION

It is well known that feed intake decreases when the dietary energy content is increasing, but feed cost increases with an increase in both dietary energy and lysine content of the diet. The reduction in feed intake with increasing dietary energy content was not enough to avoid an increase in feeding costs. Therefore feeding costs increased linearly when dietary energy and lysine contents increased. In the present study the lowest feeding cost was realized when both dietary lysine and energy content were the lowest and vice versa.

From the present study it had been seen that the income generated by different combinations of dietary lysine and energy was depending on the performance of the hens (egg weight and rate of lay). The trend in income generated for different treatments followed the trend in egg weight, and the rate of laying in both periods. Highest incomes were realised with the combination of low dietary energy and highest lysine content during peak of production, and low dietary energy with the two highest lysine contents during late production period. This was due to the higher egg weight and rate of lay associated with those combinations. On the other hand, the lowest income associated with medium energy irrespective of lysine content, was due to low performance.

Profit obtained was dependent on both performance and the cost (feeding cost) involved in achieving that performance. Therefore profit is a function of the value of the feed used (for production) and the eggs produced. Highest profits were obtained on the combinations were the margins between income (value of the eggs produced) and feeding cost (value of the feed) were highest. For example, highest profits were obtained in young hens, on low dietary energy feeds irrespective of lysine contents. This was due to low feeding costs and high income, generated by those combinations. The lowest profit obtained, under normal and 15 % reduction in egg price for all egg grades, by young hens on high energy and the two highest lysine contents, was due to the highest feeding cost not being offset by the revenue generated. Similar results were observed for old hens with the highest profit being obtained on the dietary combinations with the highest income.

The number of dietary combinations where profit declined increased when the price of the eggs increased (with young hens). This was due to a decrease in the profit margin. This implies that the profit margin is negatively correlated to the egg price. It was also observed in the present study that the effect of a 15 % increase in price for extra-large and jumbo egg grades on profit generated was greater than for an increase in all grades during peak of production. The improvement effect of price change for extra-large and jumbo eggs during production peak was due to high variation in egg weights. Profit generated from different number of dietary combinations were observed to be the same under all pricing circumstances during the late production period (with old hens). This was due to the slight variation in egg weights for different dietary lysine and energy combinations during late production, which caused a concomitantly small variation in proportions of eggs falling under a specific egg grade, for those combinations.

The result of the present study showed that the rate of decrease in income and profit within a treatment was the same at a given egg price. Feed costs were expected to change, if the rate of inclusion of ingredients changed.

GENERAL DISCUSSION

This study was designed to find out the principles to be considered when deciding upon the optimum economic method of feeding laying hens and whether these differ depending on the level of performance of the hens (age effect). Although the optimum combinations of dietary lysine and energy for hens of different ages were unpredictable from the present study, trends on feeding economic optimum were realised.

Young laying hens produce more egg materials and consume less feed when compared to older hens at a given dietary lysine and energy content. The feeding costs for older hens were observed to be R0.64 higher than for young laying hens at a given dietary lysine and energy content. This was caused by the higher feed intakes associated with older hens. For all of the various pricing structures young laying hens generated about R4 and R5 more income (at a given dietary combination of lysine and energy) than older hens. High income generated by young laying hens was associated with the 17.5 % increase in the rate of lay. The marginal difference of income versus costs generated by these two groups tends to increase when the price of eggs is increasing.

The profit margins generated were R5.43, R4.68, R6.61 and R6.49 for normal, 15 % reduction and increase in egg price, and 15 % increase in price for extra-large and jumbo, in favour of young laying hens. It can be concluded from the results of the present study that young laying hens generate more profit than the old laying hens at a given dietary lysine and energy content.

When working with young laying hens, optimum economic combination of dietary lysine and energy contents that will maximise profit depends on the production performance (egg weight and number) and the price of egg. But with older hens it depends on the feeding costs and the rate of lay (rather than egg weight), since the variation in proportion of eggs, for different dietary lysine and energy combinations, falling under a specific egg grade is small. Therefore, the combination with lowest feeding costs and highest rate of lay will yield highest profit in older laying hens.

The economic results for the present study gave some indications on the profit trends that can be achieved when working with laying hens of different ages, but it did not give the optimum dietary lysine and energy combinations for young and old hens. This was due to the dietary lysine and energy contents used, which were all sufficient to support the optimum performance of the hens. Optimum combinations that can be used to achieve optimum economic profit with young laying hens had been thoroughly investigated by previous researchers, but little is known about old hens. In order to compare the profitability of the two groups, the optimum combination that yields the highest profit needs to be predicted for old laying hens, so that the value of the feed used and product can be compared for each group. From that the profitability of those hens can be compared based on the profit generated at highest production for each group.

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APPENDIX 1

Proportions of egg grades and price depending on egg weight

Egg weight	Small	Medium	Large	Extra-large	Jumbo	Price (C/ egg)
50	4.0	46.0	39.4	10.0	0.6	24.46
51	2.5	37.8	43.3	15.0	1.4	25.17
52	1.5	30.0	45.0	20.8	2.7	25.90
53	0.9	23.0	44.3	26.9	4.9	26.65
54	0.5	17.2	41.4	32.6	8.3	27.41
55	0.3	12.5	37.2	37.2	12.8	28.16
56	0.2	8.8	32.2	40.2	18.6	28.90
57	0.1	6.1	26.8	41.5	25.5	29.62
58	0.1	4.2	21.6	40.8	33.3	30.29
59	0.0	2.8	17.0	38.6	41.6	30.93
60		1.8	13.0	35.2	50.0	31.51
61		1.2	9.7	30.9	58.2	32.01
62		0.8	7.1	26.4	65.7	32.45
63		0.5	5.1	22.0	72.4	32.82
64		0.3	3.6	17.8	78.3	33.13
65		0.2	2.5	14.1	83.2	33.38
66		0.1	1.7	10.9	87.3	33.59
67		0.1	1.2	8.3	90.4	33.73
68			0.8	6.3	92.9	33.85
69			0.5	4.6	94.9	33.95
70			0.4	3.3	96.3	34.01
71			0.2	2.4	97.4	34.06
72			0.2	1.7	98.1	34.09
73			0.1	1.2	98.7	34.11
74			0.1	0.8	99.1	34.13
75				0.6	99.4	34.15