Meeting nutritional requirements of mature broiler breeder hens.

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MEETING NUTRITIONAL REQUIREMNTS OF MATURE BROILER BREEDER HENS

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I hereby certify that research results reported in this thesis are the results of my own investigation. Where use was made of the work of others it has been duly acknowledged in the text.

S MBAMBO

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ABSTRACT

The overall objectives of this study were to compare the response of broiler breeder hens to dietary lysine at peak rate of lay and late in the laying cycle when rate of lay has declined, to compare the coefficients of response to those previously published, to determine whether there is any interaction between the response to lysine and to energy, and to compare the responses to lysine when broiler breeders are fed either wheat- or maize-based diets. Two experiments lasting 10 weeks were conducted on individually caged broiler breeder hens. In the first experiment, birds from 36 to 46 weeks of age were used, whilst in the second experiment birds from 52 to 62 weeks of age were used. In the first experiment each hen was offered 160 g/d of one of 12 dietary treatments, six dietary lysine concentrations based on both maize and wheat. In the second experiment each hen was offered 150 g/d of one of 12 dietary treatments, consisting of six concentrations of lysine at two different dietary energy levels (low and high). All the diets in both experiments were produced by diluting one of the concentrate (summit) mixes with the appropriate protein-free dilution diet. Each lysine-limiting diet was designed to supply approximately 1350 mg lysine/bird d when fed at 160 and 150g/ bird d for the first and second experiment, respectively, whilst the most diluted feed supplied only 270 mg lysine/bird d. In both experiments birds fed the highest contents of lysine consumed virtually all of the food allocated to them. However, birds on the most diluted diets consumed less than half of the daily intake of the birds on the summit feeds. By fitting the Reading Model to the data from each experiment, the coefficients of response were calculated to be 8.44E and 0.01W for wheat-based diets, 7.75E and 0.02W for maize-based diets, 10.23E and 4.57W for low energy series diets, and 9.29E and 0.01W for high energy series diets. The pooled data for both energy series produced coefficients of 9.41E and 0.00W. Since Bowmaker (1986) estimated the body weight coefficient for broiler breeders to be 11.2 it was then decided to use an assumed body weight coefficient of 10 and the *'a'* coefficient was recalculated using the equation: $a = (I-bW)/E$. The overall *a* coefficient became 15 and 13 for wheat- and maize-based diets, and 16 and 18 for low and high-energy series with a mean of 17. On the bases of the coefficients from the Reading Model a broiler breeder hen weighing 3 kg and producing 45 g of egg output per day would need 380, 349 and 423 mg of lysine/d from wheat and maize-based diets, and pooled energy series, respectively. Both the low and high-energy series curves had the same shape, implying there was no interaction between the response to lysine and to energy.

Using the calculated *a* coefficients, because they accounted for maintenance requirements, and assuming an egg contains 8.3 mg lysine/g, the efficiency of utilization of lysine for egg production is estimated as being 0.55, 0.64 and 0.49 for wheat- and maize-based diets, and pooled energy series data, respectively. The efficiency derived for the older flock is lower than the one derived for a younger flock indicating that the efficiency of utilization of the limiting amino acid for egg production declines with age in broiler breeder hens. Broiler breeder hens that were fed maize-based diets were more efficient than those fed on wheat-based diets.

GENERAL INTRODUCTION

The laying pattern of broiler breeder hens is characterized by a peak in rate of lay around 30 weeks of age with a subsequent decline thereafter. Thus, practical nutritionists generally recommend a generous allowance of nutrients early in lay followed by a period of mild regulation over the peak production period, and a subsequent reduction in the nutrient allowance as egg production declines. If no variation existed among broiler breeder hens it would be an easy task to recommend daily nutrient intakes for these birds throughout the laying cycle. However, a flock of broiler breeder hens is characterized by a high number of low or non-producers, which lowers the mean egg output of the flock. Thus birds which have the capacity to produce an egg a day are often penalized by producers when deciding on the allocation of feed for the flock on grounds that average flock egg output is only 45 to 50 g/ bird d. The response coefficients for laying hens to amino acids have been extensively quantified, but this is not true of broiler breeders. In most response trials that have been published there seems to be a wide variation in the coefficients obtained.

In laying hens it has been clearly established that older hens have a greater requirement for amino acid at a given level of egg output than do younger hens. Thus, older hens utilize amino acid less efficiently than a younger flock, but when birds of different ages are laying at the same rate the efficiency is the same, suggesting that it is not the age of the bird dietary that affects the efficiency, but rather the rate of lay or reduction in the rate with age. This has not been clearly established with broiler breeder hens.

Wheat and maize form a significant proportion in broiler breeder diets, but are acknowledged to be deficient in certain essential amino acids, particularly methionine and lysine. There is circumstantial evidence that breeders do not perform as well on wheat-based, as on maize-based diets. If the true digestibilities of lysine are known and diets formulated accordingly, then the response should theoretically be identical.

The objectives of the study were to (i) compare the response of broiler breeder hens to dietary lysine at peak rate of lay and late in the laying cycle when rate of lay has declined, (ii) to compare the coefficients of response to those previously published, (iii) to determine whether there is any interaction between the response to lysine and to energy, (iv) and to compare the responses to lysine when broiler breeders are fed either wheat- or maize-based diets.

CHAPTER 1
LITERATURE REVIEW

1.1 Introduction

The response of laying hens to dietary amino acids has been extensively investigated, but this is not true of broiler breeder hens (Bowmaker and Gous, 1991). Most of the response trials have focused on the period around peak production in the laying cycle. Little work, other than that of Goddard (1997), has been done with broiler breeders partially in the latter part of the laying period, when production has declined. If the response to amino acid were known at the peak period and latter part of laying cycle then broiler breeder hens could be more accurately supplied with the optimum amounts of each nutrient, taking into account both the long-term effect of nutrient supply on reproductive performance and the economic aspects of nutrient supply in relation to value of product.

The utilization of amino acids for egg production cannot be measured directly, as it varies in a complex manner with rate of lay. However, the efficiency of utilization can be estimated from feeding experiments and can be defined as the ratio of amino acid in the egg to amino acid used for egg production, i.e. excluding maintenance requirements. For hens in their early stages of lay (up to 40 weeks of age), the efficiency coefficient appears to be relatively constant and to vary between 0.80 and 0.85 across amino acids (Fisher, 1983).

The Reading Model (Fisher *et al.*, 1973), which is used to predict efficiency of amino acid utilization, assumes that the efficiency for egg production is constant irrespective of rate of lay. However it would appear that in laying hens the average utilization declines, as the laying year progresses, and therefore the model may not be sufficiently accurate when used to calculate requirements in older birds. A decline in average amino acid utilization occurs when the rate of lay falls below 0.5 (i.e. less than one egg every two days). To lay at such a low rate, birds must be cycling physiologically between the laying and non-laying states, and protein synthesis for egg production would therefore be intermittent. When synthesis stops there will be no utilization of dietary amino acids for egg production and thus, over a period of time, efficiencies will range from zero, at zero egg production, to 0.80 to 0.85 at an egg production rate of 0.5 or above (Fisher, 1983).

Since daily food consumption in broiler breeder hens is controlled through restricted feeding, it is essential that the daily allowances of energy and protein are adequate in order to maintain maximum egg production. To be able to meet the nutritional requirements of broiler breeder hens, it is necessary to find out whether the optimum amino acid concentration in the food would change in proportion to any change in dietary energy concentration. It is not necessary to be concerned with the effects of dietary energy and protein content on voluntary food intake of broiler breeders because food intake is restricted.

Most commercial diets are calculated on an amino acid basis, rather than protein basis. Therefore it is important to have an accurate estimate of the response of broiler breeder hens to dietary amino acids when formulating for these birds.

1.2 Amino acid nutrition

Most food allowances for broiler breeder hens have been based on the pattern of egg production predicted by the primary breeder. Their recommended is for a generous allowance early in lay is followed by a period of mild regulation over peak production and subsequent reduction in allowance as egg production decreases in the latter part of lay (Wilson and Harms, 1984).

In regard to the needs of broiler breeder hens for protein and for specific amino acids, a paucity of reports exists. Latshaw (1976) demonstrated that decreasing the dietary level of lysine in relation to the decline in the rate of lay during the laying year, had no beneficial attributes birds with rate of lay above 0.5 were penalized.

The effect of stage of lay on the protein requirement of a layer flock does not show the same relationship between egg output, body weight and the amount required of each amino acid. Egg output (measured in g/day) normally reaches a peak between 30 to 40 weeks of age and thereafter declines, but the amino acid requirement of a flock does not decline correspondingly.

Waldroup *et al.* (1966), cited by Goddard (1997), could not show any difference in performance of broiler breeder hens that were fed *ad libitum* with diets containing 13 or 17% protein, except for a reduction in weight gain of the group fed 13% protein. Pearson and Herron (1981) found that broiler breeder hens given 19.4 g protein per day performed as well as birds receiving higher protein intakes (e.g. 24.6 g/d). There were considerable differences in amino acid intakes among the protein allowances. However, in this case no associated trends in egg weight were observed. Such results cannot be used to determine the protein and amino acid requirements of broiler breeder hens. There is a need to specify minimum levels of essential amino acid when formulating poultry diets. The use of linear programming techniques has shown that both the protein level and the cost of practical rations are very much affected by assumptions made about the requirement for certain essential amino acids, particularly methionine and lysine (Fisher and Morris, 1970).

Waldroup *et al.* (1976) suggested a requirement of 418 mg lysine and 380 mg methionine per day for broiler breeders, while Pearson and Herron (1981) recommended diets that supplied a minimum of 970 mg lysine, 570 mg methionine, 300 mg cystine and 120 mg tryptophan per bird per day respectively.

Bowmaker and Gous (1991), using coefficients of response calculated from the Reading Model, concluded that an individual broiler breeder hen weighing 3 kg and producing 45 g of egg output per day, would need 793 mg of lysine and 314 mg of methionine daily. Gous *et al.* (2001), using 26, 37, 48 and 60 weeks old caged broiler breeders, estimated the digestible lysine intake to be 864, 859, 763 and 687 mg/day respectively.

A model for calculating amino acid requirement of broiler breeder hens from specified levels of production was discussed by Fisher (1998). The model considered egg output (g/d), growth, maintenance and variation amongst individual hens as determinants of requirements. Amino acid utilization coefficients for egg production were considered to be related to rate of lay and thus declined with the age of the flock. A conclusion made was that requirements for a flock being fed and producing as specified in a commercial manual (Ross Breeders Limited, 1995) reached a maximum requirement at 55 weeks of age and not at peak production as commonly supposed (Gous *et al.*, 2001).

1.2.1 Calculating amino acid requirements

The Reading Model of Fisher *et al.* (1973) is used to describe the response of laying birds to different intakes of an amino acid. The model describes the response in egg output (E, g/bird d) to amino acid intake (I, mg/bird d). It is assumed that each individual bird has a characteristic maximum egg output (E_{max}) and that, for each bird, when $E < E_{max}$, then

$$I = aE + bW$$

Where W = body weight (kg)

E = rate of lay (%) × egg weight (g)

It is also assumed that when $I<bW$, $E= 0$, thus excluding negative egg production. These relationships are illustrated in Figure. 1.1a.

When a group of birds is considered, the response is the average of all the responses for individual birds. This is shown diagrammatically for a small group in Figure. 1.1b. The graph illustrates that the group response shows three characteristics, a straight line leading through a curve to an asymptote.

In this model the group response is described by a curved line, the shape and position of which are a function of the following parameters : E_{max} , the mean maximum output; variation in E_{max} (defined by σ_{Emax}); W, the mean body weight; variation in W (σ_W); r_{EW} correlation between output and bodyweight and two constants representing the amount of amino acid required per unit of egg output (*a* mg/gE) and per unit body weight (*b* mg/kgW). It can be shown (Fisher *et al.*, 1973) that the optimum amino acid intake that yields maximum profit (i.e. the point on the curve relating cost of intake to value of output at which the slope is one) is given by:

$$I, \text{mg/d} = aE_{max} + bW + x\,(\sqrt{a^2\sigma^2_E + b^2\sigma^2_W + 2abr\sigma_E\sigma_W})$$

Where x = the deviation from the mean of a standard normal distribution which is exceeded with probability ak in one tail.

k = marginal cost per mg amino acid/ marginal revenue per g egg.

The value of x in standard units is obtained from tables and multiplied by the standard deviation of an individual's amino acid requirement. If r_{EW} is zero, the latter simplifies to $\sqrt{a^2\sigma^2_E + b^2\sigma^2_W}$

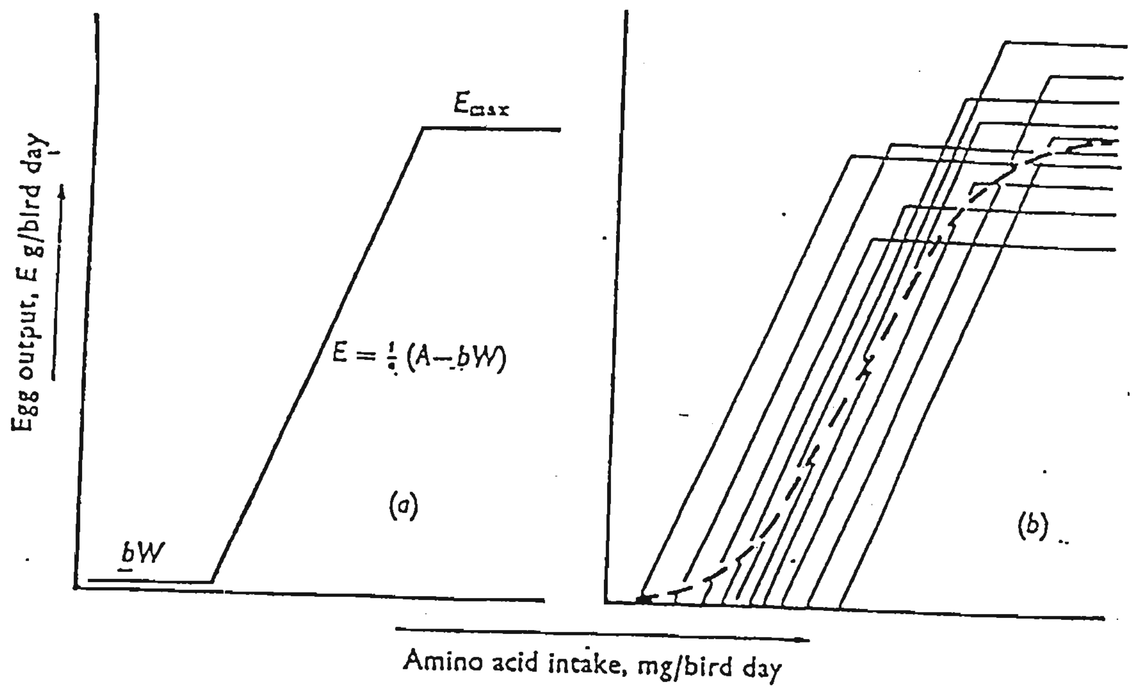

Figure 1.1 The model for the response of laying hens to amino acid intake (a) the response of an individual bird (b) individual (-) and mean (- -) responses for a smaller group of birds. See text for meaning of symbols. (From Fisher *et al.*, 1973).

1.2.2 Maintenance requirement for amino acid

In order to grow and produce eggs, birds must exist and continue to exist. The function of continuing to exist unchanged is usually called maintenance (Emmans and Fisher, 1986). Bowmaker and Gous (1991) calculated the amount of amino acid required for maintenance of body weight as (amino acid intake - *a*E)/W. They found the amounts of lysine required for maintenance of body weight, assuming an '*a*' value of 10 and 7.9 mg/g egg for lysine, to be 82.75mg lysine/kg. Broiler breeder hens have considerable lipid reserves, and because it can be argued that there is no energy cost of maintaining such lipid reserves (Emmans and Oldham, 1989), it is likely that amino acid requirement for maintenance (as defined by the *b* value of the Reading Model) over different types of poultry would be more closely related to body protein content than to body weight. A more accurate estimate of the amount required for maintenance, when comparing laying hens of different size and body composition would therefore be that related to the protein content of the body (Emmans and Fisher, 1986).

Maintenance requirements for amino acids are related to feather–free body protein weight as suggested by Emmans and Fisher (1986).

The expression used is:

$MPr = BP_m^{-0.27} \times x\,BP$

Where MPr = maintenance protein requirement, grams per day, expressed as ideal protein; BP_m = feather-free body protein weight at maturity; BP = feather-free body protein weight; and x = a constant, for which a value of 8 g/kg was suggested by Emmans and Fisher (1986).

1.2.3 Efficiency of amino acid utilization

The efficiency with which amino acids are utilized for egg production can be determined by comparing the estimates of the coefficient for egg output with the amount of amino acid deposited in the egg (Goddard, 1997). Fisher (1980) and McDonald and Morris (1985) calculated the efficiency of conversion of dietary amino acid to egg protein for laying hens and found that it ranged between 0.74 and 0.85. Bowmaker and Gous (1991), working with broiler breeders, found the mean efficiency to be 0.47 for lysine, but not all the birds were laying at a rate of >0.5. A summary of published estimates of the efficiency of utilization coefficients is shown in Table 1.1.

In order to test the hypothesis that broiler breeders laying in closed cycles have the same net efficiency for egg production as laying hens, Bowmaker and Gous (1991) excluded birds laying fewer than 14 eggs in the final 28 day period, i.e. birds laying at less than 50%, from the analyses. For lysine, the coefficient for egg production decreased from 16.88 to 13.9 and the maintenance coefficient also decreased from 11.2 to 0.56. These adjusted coefficients resulted in an efficiency of 0.57 for lysine, a value closer to those suggested for laying hens than the previous value of 0.47.

There are large differences in protein utilization between birds differing in stage of lay. In laying hens, it is clearly established that as a flock ages the average utilization of limiting amino acids for egg production declines (Wethli and Morris, 1978).

Table 1.1. *Efficiency coefficients of utilization of amino acids for laying hens and broiler breeder hens*

Literature source	Bird	'a' (mg/g egg)	lysine (mg/g egg)	Efficiency
Connor (1982)[1]	Layers	10.71	7.90	0.74
Griessel (1980)	Layers	10.49	7.90	0.75
Latshaw (1976)	Layers	7.89	7.90	1.00
McDonald (1979)	Layers	13.29	7.90	0.59
Morris (1981)	Layers	8.28	7.90	0.95
Pilbrow and Morris (1974)	Layers	10.26	7.90	0.77
Goddard (26 weeks) (1997)	Breeders	14.04	8.30	0.59
Goddard (37 weeks) (1997)	Breeders	14.25	8.30	0.58
Goddard (48 weeks) (1997)	Breeders	14.23	8.30	0.58
Goddard (60 weeks) (1997)	Breeders	12.19	8.30	0.68
Bowmaker and Gous (1991)	Breeders	16.88	7.90	0.47

[1] Cited by McDonald and Morris (1985).

'a' = an estimate of the amount (mg) of amino acid required to produce 1 g of egg output.

Amino acid requirements should not be stated as proportions of the diet nor as ratios with dietary energy. Rather, the optimum daily intake of each amino acid should be calculated according to the method of Fisher *et al.* (1973), together with optimum energy concentration (Gous and Bowmaker, 1986).

1.3 Problems associated with the Reading Model for broiler breeder hens

In order to be able to fit the Reading Model to any data set, seven parameters must be specified : maximum egg output of the flock; the mean body weight of the flock; the standard deviations within the flock of maximum egg output and body weight; and starting values for the two coefficients to be estimated. Bowmaker and Gous (1991) found that there are difficulties in deciding upon values for these parameters, especially in the case of broiler breeders fed on diets with a wide range of amino acid contents. They observed that body weight was influenced by the treatments, and that the mean body weight chosen for the birds in such a response trial cannot reflect the differences between treatment means. By estimating a single weight for all the treatments, the amount of each amino acid required for maintenance would have been overestimated for the lighter birds (those on poor treatments) and underestimated for the well-fed birds.

According to the literature, the coefficient of variation (CV) of egg output, when all birds are laying, is in a region of 0.08 to 0.10. As the number of non-laying birds making up the mean egg output increases, so the CV increases substantially. When fitting the model, the user must be aware that some of the parameters might sometimes need to be treated differently, because the resultant equation will not be appropriate under all circumstances, the effect in such cases being not dissimilar to an empirical equation that fits the data set from which it was derived but which cannot be extrapolated to other sets (Bowmaker and Gous, 1991).

1.4 Energy requirements

Changes in dietary energy concentration modulate feed efficiency through two partially dependent pathways. Firstly, as dietary energy increases, energy needs are satisfied with decreasing feed intake; secondly, growth rate is promoted by increasing dietary energy content, provided that no other nutrient is limiting. The latter was also confirmed by Gous *et al.* (1987) using layers, where they found that feeding different concentrations of methionine, lysine and isoleucine at different energy levels did not have an influence on egg output, but rather than an effect on food intake. Morris (1968) demonstrated that laying birds consume less energy as the energy concentration of the diet is reduced and over-consume energy as the energy content of the diet is increased. Gous and Bowmaker (1986) reported that when protein content of the feed is limiting it affects the efficiency with which birds utilizes dietary energy for the purpose of egg production and tissue formation. The allocated amount of feed is also important, in that it affects the efficiency of energy utilization for maintenance purposes

Restricting food intake has been shown to have a significant effect on energy requirements. Jackson (1970, 1972) using laying hens fed on a concentrated diet, which allowed consumption of excessive amounts of ME, observed that considerable reductions in ME intake below *ad libitum* level could be effected without any significant adverse effect on egg number or egg size. Petersen (1971), using diets of varying ME concentrations, observed that egg production and egg size could be maintained at ME intakes considerably less than those normally recommended for laying hens. If diets are concentrated with respect to protein, major minerals, trace elements and vitamins, it is possible to decrease energy intakes without any adverse effect on productivity (Petersen, 1971). Broiler breeders are not fed *ad lib,* which makes it easier to formulate diets than when birds are given *ad lib* access to food provided the precise requirements are known.

In the literature reports regarding the amount of energy required for broiler breeders is almost as contradictory as that for protein or amino acid requirements. Auckland and Fulton (1973) discovered that feeding markedly less energy than birds would voluntarily consume may support near maximum output but only for the relatively short periods of time required for depletion of expendable body reserves. Van Wambeke (1977) observed that 1780 to 1880 kJ AME/bird d gave the highest performance and highest gross profit from Ross and Hubbard strains of broiler breeder in a temperate climate. Thus a lower rate of egg production on low energy allowance (1500 kJ AME/bird d) is consistent with a failure of the allowance to meet the bird's energy requirements for egg production (Pearson and Herron, 1981). Wilson and Harms (1986) found that an average daily consumption of 2090 kJ ME/bird d during peak lay resulted in significantly higher production than a "standard " feeding regimen of 1674 kJ ME/bird d. This is in agreement with the results of Bowmaker (1986) who recommended an amount of 2000 kJ AME/bird d. In contrast, Spratt and Leeson (1987) concluded that 1610 kJ ME/bird d was sufficient to maintain normal performance through peak production. When energy is increased from a low to a high level, a decrease in production results. This is thought to be due either to the deposition of lipid that results from the intake of energy in excess of the requirements for maintenance and production, or to the fact that the growth of broiler breeders is restricted throughout their lives, therefore they might have room for body protein growth once their allowance is increased in terms of nutrients.

1.4.1 Predicting energy requirements

Prediction equations to determine the energy intake of laying birds have been developed by partitioning metabolisable energy (ME) requirements into that required for egg production, maintenance and tissue formation in the form:

$$\text{ME intake (MJ/bird d)} = aE + bW + cDW$$

Where E is egg output (g/bird d), W is body weight (g) and DW is change in body weight (g/bird d) (Gous *et al*, 1978; McDonald, 1978). However, these partition equations have been developed from the results of feeding one feed *ad lib* to birds, whereas it might be expected that birds:

(i) Partition energy differently if fed adequate versus inadequate amino acid levels. At inadequate levels, feed intake is increased to compensate for the deficiency (Emmans, 1974) with a resultant wastage of energy, and

(ii) Utilize energy more efficiently if feed is restricted rather than fed *ad lib.* When feed intake is reduced, maintenance requirements are reduced due to a lower metabolic rate (Kleiber, 1975).

Romanoff and Romanoff (1949), cited by Emmans (1974), explained that eggs vary in their relative amounts of yolk, albumen and shell and, since yolk contains considerably more energy than either albumen or shell, the energy content of eggs will vary. Eggs have an energy content of about 6.7 kJ/g. The efficiency of converting ME to egg and carcass energy is about 80%. Taking the energy contents of carcass weight change and eggs to be 16.7 kJ/g and 6.7 kJ/g, respectively, and assuming an efficiency of converting dietary ME of 80%, Romanoff and Romanoff concluded that the ME needed for production can be estimated as:

$$[2E + 5\Delta W] \times 4.184 \text{ kJ ME/bird d}$$

where E = egg output in g/bird d and ΔW = weight change in g/bird d.

Actual determinations of the efficiency by feeding varying amounts of energy at each of several temperatures would be expected to show that the efficiency is greater at lower temperatures as at such temperatures that the heat released as a result of production (estimated as 1 energy unit for 4 energy units stored) should help the animal meet the environmental demand for heat. Verstegen *et al.* (1973), cited by Emmans (1974), found this to be the case with pigs. The above expression for the ME needed for production is therefore likely to be accurate enough for most purposes and to be affected by temperature.

ME intake (in kJ/d), as a function of body weight, growth, egg output and temperature can now be estimated from the equations shown below, which was developed by Emmans (1974) for the white strains of laying hens, as follows:

$$ME = W[115 + 2.2(25 - T)] + 2E + 5\Delta W$$

$$= [W(170 - 2.2T) + 2E + 5\Delta W] \times 4.184 \text{ kJ ME/bird d}$$

1.5 Factors influencing egg size and composition

The size and composition of the egg are dependent upon the nutritional status, body weight, age, genetic make up of the hen and the lighting regime used during both the rearing and laying periods. Commercial broiler breeder hens, whose genetic propensity for growth is considerably greater than that of their egg-laying cousins, produce an egg that is approximately the same size, despite a difference in body mass of about 800 – 1000 g (Etches, 1996). Age is a major determinant of egg size in all forms of poultry. At the onset of lay, egg weight is much smaller than in subsequent weeks. The increase in egg size with age is a result of an increase in yolk, albumen and shell weight, although these increases are not proportional (Etches, 1996). Fletcher *et al.* (1983), working with layers, concluded that increasing yolk yield was equally dependent upon increasing egg weight and flock age. Increasing albumen was found to be a positive function of egg weight but a negative function of flock age.

Egg amino acid composition is largely determined by the proportions of yolk, albumen, and shell and by the dry matter content of these components (Fisher, 1998).

Fisher (1980), McDonald and Morris (1985), and Smith (1978a and 1978b) described the protein content of the egg as follows:

A typical egg weighs about 58 to 60g 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. The remaining 3 to 4% of the protein is in the shell and its associated membranes.

Lunven *et al.* (1973) measured the lysine content of the yolk and albumen, and their results are given in Table1.2.

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

Variable	Yolk	Albumen
mg lysine/g N	477	378
mg lysine/g	12.87	6.42

In most of the published literature, amino acid composition of eggs has been assumed to be constant across ages and different strains. David and Roland (1979), working with laying hens, observed that from the third to the twelfth month of lay, egg weight increased by 8.12 g. With egg weight increasing by 14.5% during the nine month period, and shell weight increasing only by 2.9%, specific gravity decreased by 12 units. During the same nine-month period, shell thickness also decreased by 0.014 mm. The increase in weight was partially due to an increase in the yolk. Heavier eggs have more yolk relative to albumen than smaller eggs.

Goddard (1997) suggested that the efficiency of amino acid utilization for broiler breeder hens decreases with age as in laying hens.

1.6 Rate of lay

1.6.1 Age and rate of lay

Fisher and Morris (1967) found no indication that the amount of protein needed for maximum egg output was any less in one period than in another. However, in all cases in which responses to protein have been measured independently in the flock at different stages of the first laying year, nutrient utilization has been lower in the older birds (Fisher, 1976). The small differences in body weight over such a period do not provide a satisfactory explanation for this observation (Griessel, 1980). 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 and Morris 1970; Fisher, 1976; Wethli and Morris, 1978). This can be seen from Figure 1.2 where response to protein intake of two flocks with different age groups is shown. Fisher (1970) demonstrated that about half of the decline in efficiency of methionine utilization, which occurs during the laying year, is due to the presence of poor producing birds in the flock. The other half of the decline presumably reflects some real change in metabolic efficiency in the ageing bird as shown in Figure 1.3.

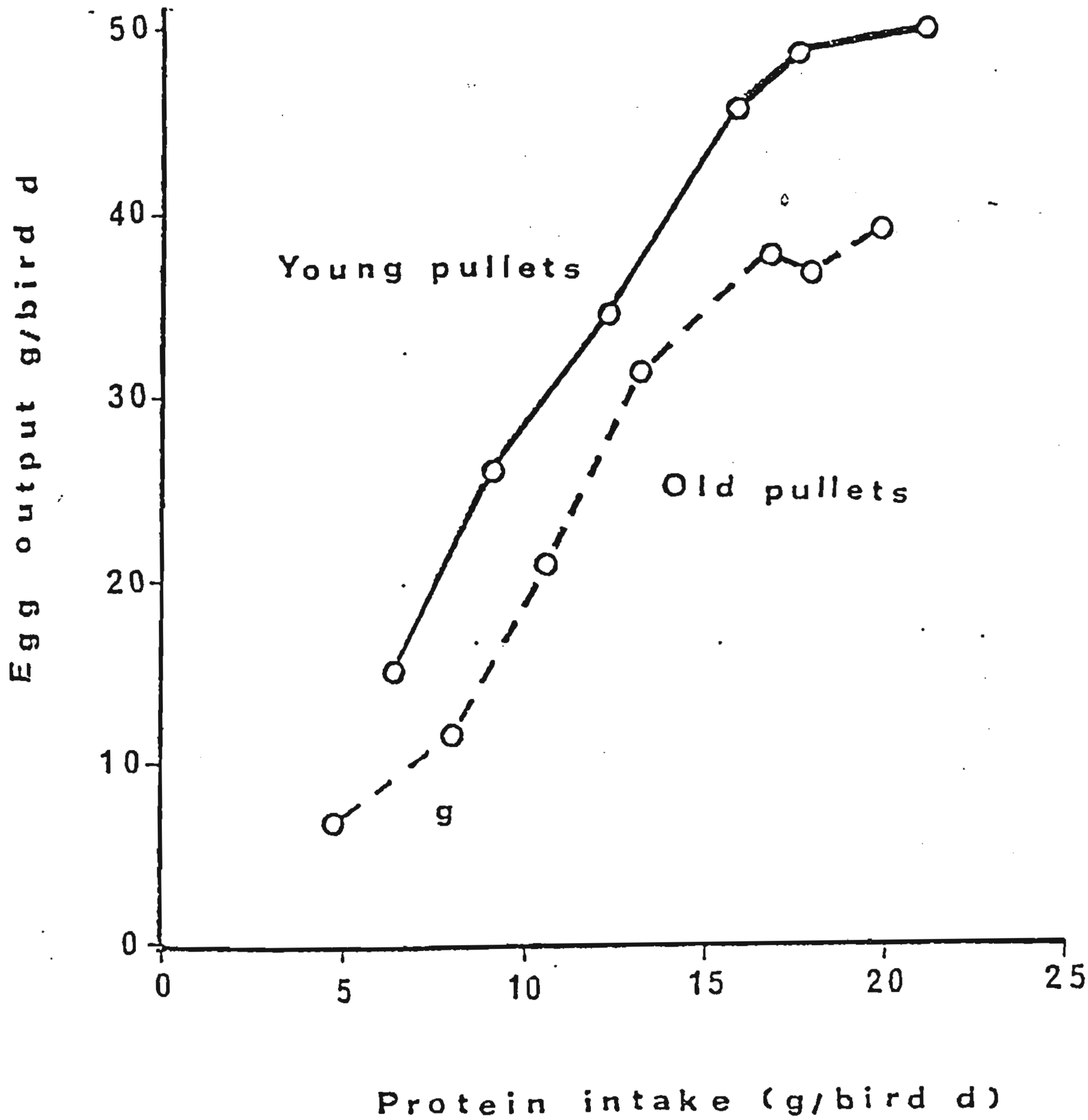

Figure 1.2 The response to graded levels of dietary protein at two different ages (Jennings *et al*, 1972).

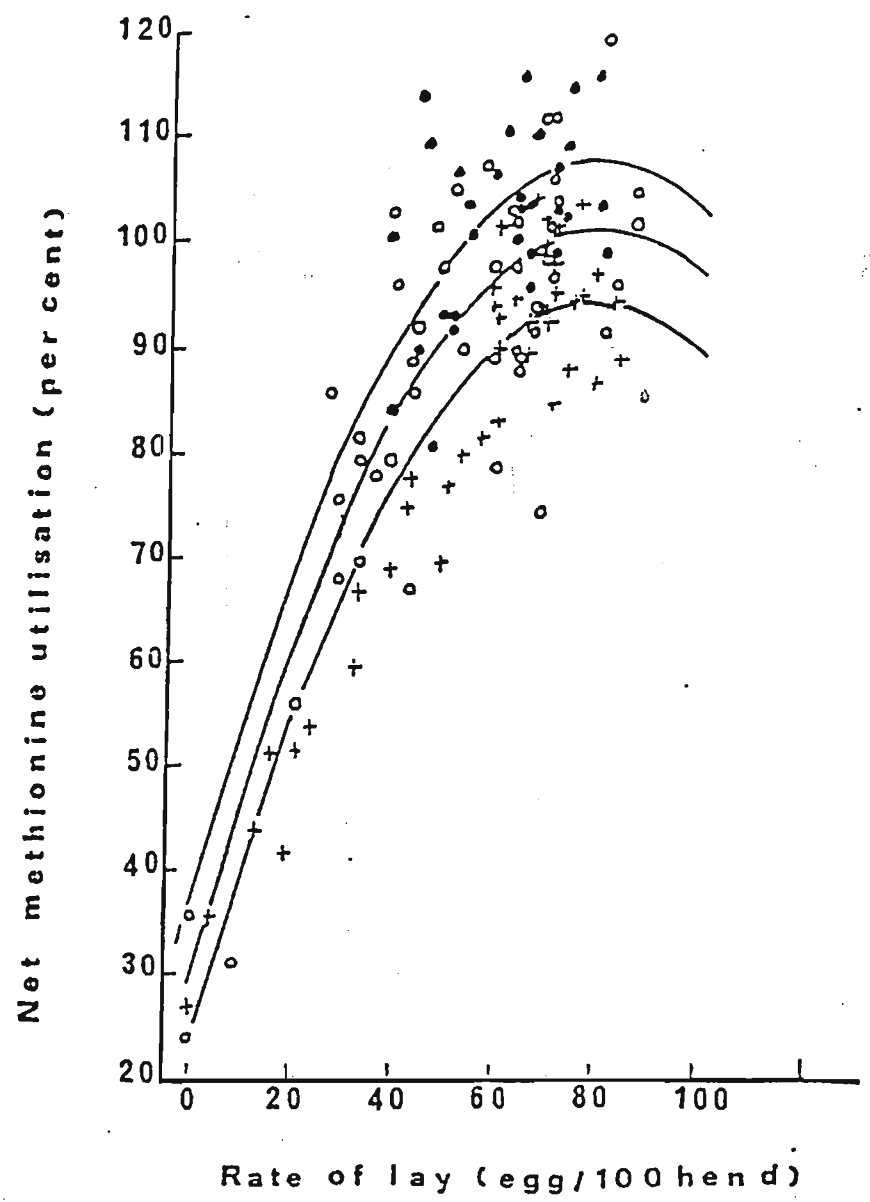

Figure 1.3 The relationship between net methionine utilization and rate of lay in individual laying pullets of three ages:- 30 to 40 weeks ( ), 45 to 55 weeks ( ), 60to 70 weeks (+).

All birds received a diet containing 0.156 percent methionine which was shown to be the first limiting nutrient. Net methionine utilization = methionine/ methionine intake where methionine utilized = 4E + 25W + 3.0ΔW. The curves are parallel quadratic regressions (From Fisher., 1970).

If birds of different ages are laying at the same rate, then efficiency is the same, suggesting that it is not the age of the bird that affects efficiency but rather the rate of lay. This was also demonstrated by the work of Wethli and Morris (1978) where egg output in response to different intakes of tryptophan was measured in young pullets (32 weeks), older pullets (63 weeks) and moulted hens (Figure 1.4). From Figure 1.4 it is clear that the response to tryptophan intake was almost identical in the force-moulted hens and younger pullets. However, compared with younger layers the egg output on similar tryptophan intakes was considerably lower for the older hens. This work indicates that the reason for poor utilization must not be sought in age. Wethli and Morris (1978) pointed out that some of the older birds were moulting and the allowance for feather growth was therefore appropriate. This allowance, however, seemed unlikely to exceed 2 mg/hen d. Because maintenance requirements per kg bodyweight had increased from 4 to 17 mg/hen d, another explanation for the higher requirement is needed.

Wethli and Morris (1978) concluded that since the efficiency of the force-moulted birds improved as a result of a rest period, the oviduct requires a restorative period to return to its optimal physiological efficiency.

Part of the decline in apparent efficiency of amino acid utilization can be accounted for by the presence in the flock of pullets that are not laying eggs. The inevitable result is that on non-egg forming days they take in more protein than is needed for maintenance and so their amino acid intake is largely wasted, and the average utilization of amino acid by the flock is depressed.

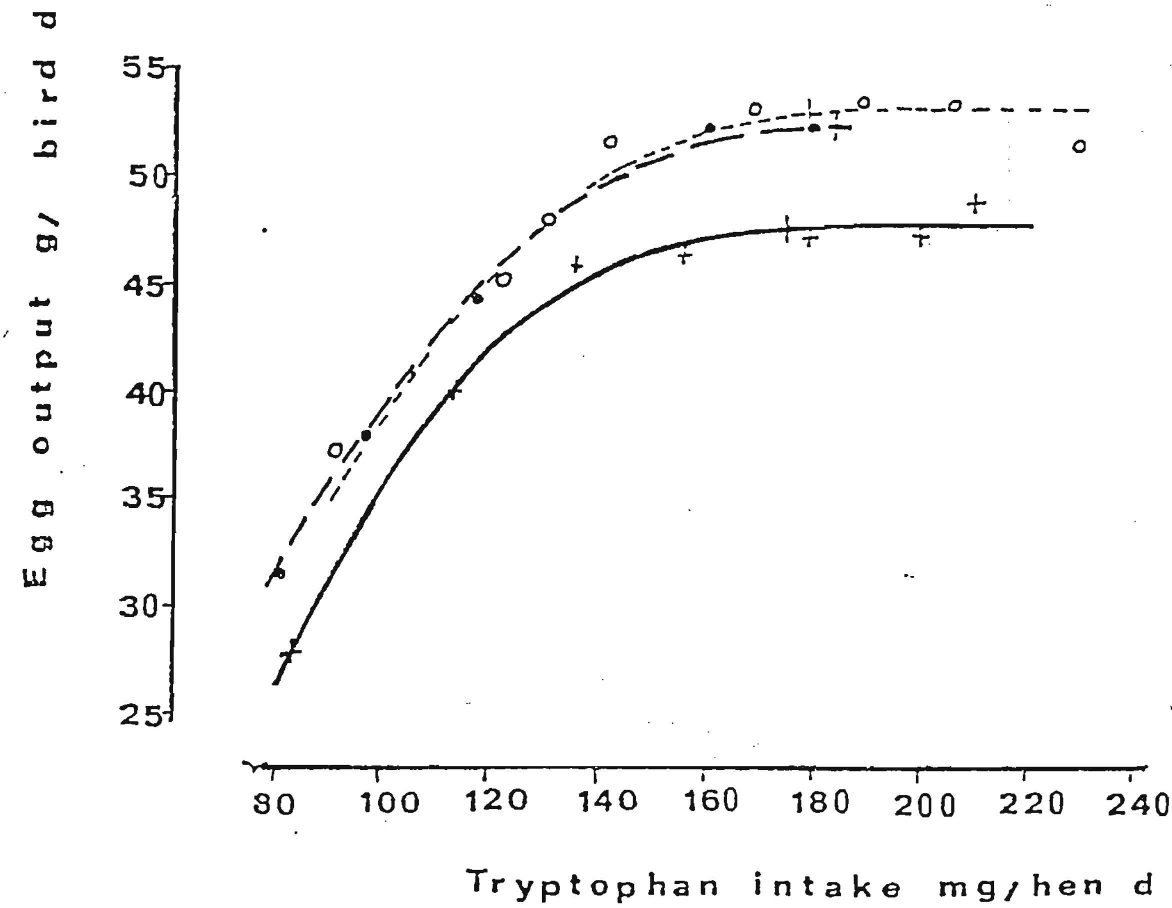

Figure 1.4 Responses to diets supplying different concentrations of tryptophan in three experiments. Young pullets (experiment 2), • - - •; older pullets (experiment 3), + — +; moulted hens (experiment 4), o - - -o. Vertical marks on the response curve represent optimal tryptophan intakes calculated by methods described in the text (Wethli and Morris, 1978).

1.6.2 Egg weight and Rate of lay

Egg weight declines as the amino acid supply is reduced when hens are fed diets limiting in an amino acid. This was demonstrated by Morris and Gous (1988) with laying hens, and by Bowmaker and Gous (1991) with broiler breeders. However, these publications indicate that egg weight does not decrease to the same extent as rate of lay

Morris and Gous (1988) analyzing data from a wide range of published trials, showed that egg weight and rate of lay were affected to the same extent, until the amino acid supply was reduced to about 0.9 of that required for maximum output (Figure 1.5). Egg size did not fall below 0.9 of its maximum value until amino acid supply was well below 0.5 of the optimum intake, whereas rate of lay was only about 0.7 of its potential value when amino acid intake was 0.5 of the optimum.

Bowmaker and Gous (1991) showed that egg weight and rate of lay in broiler breeders were affected to the same extent until the amino acid supply was reduced to 0.64 of that required for maximum output. As amino acid supply was reduced further, rate of lay declined almost linearly to 0.2 of the maximum, whereas egg weight, at the lowest point, was 0.8 of the maximum.

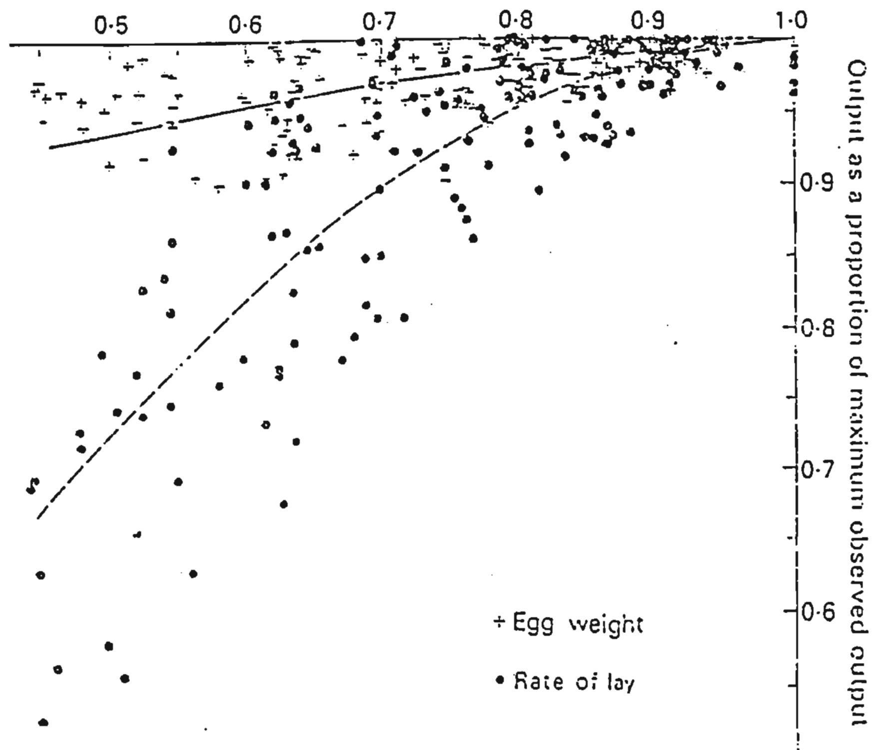

Figure 1.5 The relationship between intake of a limiting amino acid and rate of lay (- - -) or egg weight (—). This figure omits 15 pairs of data points which lie to the left of AAIN = 0.45 AAMAX and also 23 data points for egg weight = 1.0 and 27 data points for rate of lay = 1.0 all of which occur at AAIN = 1.0 (Morris and Gous, 1988).

1.6.3 Effect of rate of lay on energy requirements

Waring and Brown (1965) obtained evidence to suggest that the starving metabolic rate of the laying hen was higher than that of the non-laying hen. In their work there was a 20% increase in the metabolic rate of the laying hen as compared with the non-laying hen. Tasaki and Sasa (1970) observed a similar result with a 26% difference during the first three days of fast.

1.7 Conclusions

The greatest problem facing the broiler breeder industry is depressed laying performance throughout the laying cycle. Broiler breeders are fed restricted amounts of feed through the growing and laying period to prevent excessive body weight gains and to prevent poor egg production. Thus, energy and other nutrients can become limiting if the feed restriction is too severe.

Efforts to formulate diets in order to maximally utilize the amino acid in the feedstuff are often frustrated by the absence of consistent estimates of amino acid availabilities. Data for the total amino acid content of feedstuffs are accumulating, but these amino acids may not be available to birds, for a number of reasons. Diets are calculated on feed consumption and analyses information; the assumption usually made is that amino acids are 80-90% available. In countries where wheat normally forms a significant proportion of poultry diets, there has been reports that production increases if producers switch from wheat to maize. The first objective of this study was to compare the amino acid digestibilities of these two ingredients and to validate this claim through measuring the response to lysine of broiler breeders when fed either a wheat or maize based diet.

Energy requirement is a function of body size, egg output and environmental temperature. In mature birds, the question arises whether they should be or need to be growing, and if so, whether this growth is in lipid, protein or both. This is more important in broiler breeders, as their growth has been restricted throughout their lives. Hence, they may still have the capacity to grow body protein and lipid once they have started laying. Laying pullets on the other hand, do not grow body protein, only lipid, once they start laying. Increasing dietary energy concentration reduces food intake and promotes growth rate, provided no other nutrient is limiting. The second objective of the study was to test whether there is any interaction between protein and energy at high dietary protein and energy levels with respect to the responses.

Older laying hens have a greater requirement for protein at a given level of egg output than do younger hens. It is therefore unwise to reduce protein intake as the laying year progresses because older laying hens utilize amino acid less efficiently than a younger flock. While this hypotheses is true for laying hens, only Goddard (1997) has demonstrated this with broiler breeder hens. The third objective of this study was to test this hypotheses through comparing the data obtained from both experiments.

CHAPTER 2

RESPONSE OF 36 TO 46 WEEK OLD BROILER BREEDER HENS TO DIETARY LYSINE WHEN FED MAIZE AND WHEAT BASED DIETS

2.1 Introduction

Cereals supply a significant proportion of amino acids in poultry diets (Green *et al.* 1987) but are universally acknowledged to be deficient in several of the essential amino acids, particularly lysine and methionine (D'Mello, 1993).

Green *et al.* (1987) compared digestibilities of amino acids in maize, wheat and barley, using intact and caecetomised cockerels. The results indicated that lysine was the least digestible of all amino acids, in maize compared to wheat and barley. However, there is circumstantial evidence that breeders do not perform as well on wheat-based, as on maize-based diets, which is in contrast to what Green *et al.* (1987) reported. If the true digestibilities of lysine were known then it would be possible to understand the cause of variation in performance between breeders fed either wheat or maize based diet.

The objectives of this study were to compare the digestibilities of lysine in wheat and maize, and also to compare the response to lysine when broiler breeder hens are fed either a wheat or maize based diet.

2.2 Materials and methods

2.2.1 Birds and management

Four hundred and sixty eight Ross broiler breeder hens aged 36 weeks were housed in a controlled environment house. Each hen was kept individually in a wire cage (55 cm high, 40 cm wide and 45 cm deep), equipped with two nipple drinkers with drip cups, and a feeder (15cm wide, 13cm deep). The house was cross-ventilated with six fans; light-tight due to baffles over the fan openings and insulated. The lighting regime used throughout the experiment was 16L : 8D. The experiment was conducted for ten weeks, ending when the hens were 46 weeks of age. Prior to the start of the experiment, all birds had been kept on a restricted feed schedule, being fed 150g/bird d of a commercial broiler breeder feed (14% protein; 11.7 MJ AME/kg feed) from the age of 22 weeks.

2.2.2 Experimental design

Thirty nine birds were assigned to each treatment, with rate of lay in the previous ten weeks being used as a blocking factor. There were six blocks with each treatment appearing twice in the block.

2.2.3 Dietary treatments

During the experimental period (10 weeks), the hens were fed one of twelve dietary treatments designed to have lysine as the first limiting amino acid, six diets being based on wheat, whilst the other six were maize based. The diets were mixed by diluting two concentrated (summit) mixtures with a (practically) protein-free dilution mixture (Table 2.1) according to the technique described by Fisher and Morris (1970) modified by Pilbrow and Morris (1974). The summit diets were designed to supply approximately 1350 mg lysine/bird at an intake of 160g/bird d. This intake of lysine was calculated to provide approximately 1.2 of the requirement for lysine of a 3.1 kg broiler breeder hen producing 70 g egg output/d, based on coefficients of response published by McDonald and Morris (1985). Requirements for all other amino acids were calculated in a similar manner, the amounts in the summit diet providing a minimum of 1.4 of the requirement for each amino acid.

The summit diets and the dilution diets were analysed for protein, digestible amino acids, calcium and phosphorus content (Table 2.1). AME was measured using the method of Fisher (1982) in which 50 g of the diet is given by tube (Sibbald, 1976) following a 48 h fasting period, and excreta were collected over the following 48 h and oven dried. The AME value was corrected to zero N retention and to reflect an intake of 80 g/d ($AMEn^{80}$). During the initial 48 h fasting period, 100g of glucose water (50 g glucose) was fed to all birds to maintain a positive energy balance.

Table 2.1. *Chemical composition (g/kg) of the summit and dilution diets on as fed basis.*

Ingredients	Summit 1	Summit 2	Dilution
Yellow Maize	-	435	-
Wheat	440	-	-
Soyabean 48	136	148	-
Sunflower oil cake	250	250	-
Sunflower oil	67.6	61.4	100
DL - Methionine	1.9	1.8	-
Limestone	90	89	90
Monocalcium phosphate	8.5	10.8	14
Vitamin + mineral premix[1]	2.5	2.5	2.5
Salt	2.5	2.7	2.7
Sodium bicarbonate	1.0	1.3	0.8
Plasterer's sand (Filler)	-	-	122
Starch	-	-	273
Sugar	-	-	273
Sunflower husks (Filler)	-	-	122
Analysis	**Actual**	**Actual**	**Actual**
AME (MJ/kg)	11.2	11.0	10.8
Crude protein (N×6.25)	221	190	7
Lysine	8.30	7.16	-
Methionine	5.40	4.37	-
Threonine	6.50	4.93	-
Tyrosine	4.80	3.55	-
Arginine	14.5	11.7	-
Histidine	5.12	4.24	-
Isoleucine	8.99	7.12	-
Phenylalanine + Tyrosine	14.8	16.0	-
Valine	10.8	8.76	-
Calcium	53.4	53.5	24.0
Available Phosphorus	7.0	7.4	1.5

[1] Standard commercial broiler breeder vitamin and mineral premix.

The zero N retention was measured by feeding glucose to another set of cockerels after the 48 h fasting period and subsequently collecting excreta after another 48 h. Results from these analyses were used to calculate endogenous energy loss which was later used as a correction factor. AME was calculated as; AME/g food = energy intake/g food – energy excreted/g food and TME was calculated as; TME = AME/g food + EEL/g food and final N correction was calculated as AME_{80} = TME – EEL/80. The energy content of the feed and excreta were determined using bomb calorimeter.

Protein was measured as nitrogen × 6.25 using the LECO Nitrogen Analyser in which the sample is loaded into a combustion chamber at 1050°C with an autoloader. Oxygen flows over the sample which, together with the furnace, causes the sample to combust. The combustion process will convert any nitrogen into N_2 and NO_2. The gases then pass through two Anhydrone® tubes. Sample gas in the aliquot doser, is swept by the carriers gas (He) to the catalyst heater where NO_2 gases are reduced to $N_2.CO_2$ and water is removed. The N_2 and He flows through one side of thermo-electrical (TC) cell. Carrier gas, filtered by a scrubber, flows over the other side of the TC cell. The gases on both side of the TC cell are compared and an output voltage results. This voltage is fed to the computer, displayed and stored as the N_2 measurement result.

Amino acids were determined by using high sensitivity protein hydrolysate analyses using a Beckman 6300 instrument and Application Data A6300-AN-002 (Moore and Stein, 1948 and Beckman instruments, 1983). This is a single column method using three sodium elution buffers, a regenerating reagent, and a sodium High-Performance Column. The standard protein hydrolysis procedure uses 6 N HCL at 110° for 24 hours. The internal standard is added to the sample. The chromographic and control data is passed back and forth between the System Gold computer and the Beckman analyser; and calcium and phosphorus were analysed using the AOAC (1990) methods of analysis.

The mixing of the summit and dilution diets and subsequent blending took place at the research farm (Table 2.2). Feeds 6 and 12 were mixed by supplementing each of Feed 5 and 11 with 2 g lysine/kg, in order to confirm that lysine was the most limiting amino acid in the basal feed.

Table 2.2. *Blending proportions of the summit and dilution diets to produce the experimental diets on as fed basis*

Feed no.	Energy Content	Lysine as proportion of requirement	Other amino acids as proportion of requirement	Summit (S) (%)	Dilution (D) (%)
				S1	D1
1	11.20	1.30	1.40	100.0	0.0
2	11.12	1.04	1.12	80.0	20.0
3	11.04	0.78	0.84	60.0	40.0
4	10.96	0.52	0.56	40.0	60.0
5	10.88	0.26	0.28	20.0	80.0
6[1]	10.88	0.46	0.28	20.0	80.0
				S2	D2
7	11.00	1.20	1.40	100.0	0.0
8	10.96	0.96	1.12	80.0	20.0
9	10.92	0.72	0.84	60.0	40.0
10	10.88	0.48	0.56	40.0	60.0
11	10.84	0.24	0.28	20.0	80.0
12[1]	10.84	0.44	0.28	20.0	80.0

[1] 0.2% lysine added as 78.4% lysine-HCl.

S1 = Wheat-based summit diet; S2 = Maize-based summit diet

2.2.4 Allocation of diets

Daily food allocation (160 g/bird) was measured into plastic-coated cardboard containers up to 8 d before being fed to the hens. Feeding took place at the same time each morning.

2.2.5 Measurements

2.2.5.1 Bodyweight

Bodyweight was recorded at the beginning of week one, week six and at the end of week ten.

2.2.5.2 Food intake

Food remaining in each feed trough at the end of each day was not removed but was allowed to accumulate until the end of each week, where after it was removed, weighed and discarded. Daily food intake was calculated by multiplying the daily allocation by seven and subtracting the amount remaining at the end of each week and dividing by seven again.

2.2.5.3 Egg numbers and egg weights

Egg numbers were recorded daily. All the eggs were weighed on three days of every week. Egg output was calculated for each week by multiplying the daily rate of lay during the week with the mean egg weight for the week.

2.2.5.4 Mortalities

Mortalities were recorded, with dead birds being regarded as 'missing plots'.

2.2.5.5 Chemical composition of the body

Twenty-four birds, two from each treatment, were sacrificed by carbon dioxide asphyxiation at the end of trial. The birds were selected to represent the treatment variation in rate of lay. This was done by selecting a persistent laying and non-laying or poor laying bird from each treatment. The birds were then plucked, minced and analysed for body protein (BP) ash, water and lipid.

2.2.5.6 Lipid-free body weight

For the 24 birds that were sacrificed and analysed at the end of the experiment, the lipid-free body weight (LFBW) was calculated by subtracting the amount of fat in the carcass from the body weight. LFBW was later used to calculate maintenance requirements of the birds.

2.2.6 Statistical Analyses

An analysis of variance was performed on the data using a general linear model to obtain treatment means over the final four weeks of the experiment and to test the blocking effect. The independent variables included in the model were treatments and blocks. No interactions were tested. The response variables were body weight, change in body weight, rate of lay %, egg weight, egg output, food intake and lysine intake. The effect of blocking was tested by running an analyses of variance on the response variables in the GLM using blocks as the prediction parameter. Data from this period were used on the assumption that by this time the response of the birds to the treatments would have stabilised. Minitab (1998) was used for statistical analyses.

2.3 Results

2.3.1 Experimental diets

The results in Table 2.3 were obtained by bioassay with intact cockerels as described for AME. Whole wheat was used in this assay.

Table 2.3. *Chemical analyses of digestible lysine for wheat and maize on as fed basis*

Lysine	Wheat	Maize
Digestible (g/kg)	1.95	2.45
% Digestible	47.93	89.75

Table 2.4. *Mean response to different lysine levels of variables measured over the final 4 weeks of the trial*

	Body weight (g)				Change in body weight (g)			
Diets	Wheat	SE	Maize	SE	Wheat	SE	Maize	SE
1	3850	55.9	3927	43.4	81.4	37.3	79.2	19.4
2	3898	70.9	3861	35.7	109.4	37.5	129.7	30.8
3	3870	46.7	3849	49.4	78.9	16.4	69.5	17.9
4	3626	53.3	3637	49.5	17.1	44.0	-11.7	32.0
5	3239	90.3	3347	85.1	-118.9	54.9	-69.7	48.8
6	3235	80.5	3503	111	-117.8	50.1	107.7	91.9

	Rate of lay %				Egg weight (g/bird d)				Egg output (g/bird d)			
Diets	Wheat	SE	Maize	SE	Wheat	SE	Maize	SE	Wheat	SE	Maize	SE
1	67	2.45	71	2.13	69	0.79	67	0.79	47	1.52	49	1.39
2	67	2.60	72	1.45	65	0.74	68	0.71	45	1.78	49	0.94
3	69	1.75	68	1.92	69	0.70	68	0.73	48	1.11	47	0.72
4	64	1.90	60	1.82	65	0.64	65	0.87	41	1.05	40	0.67
5	40	2.02	37	3.04	60	1.82	56	1.00	26	1.39	22	1.77
6	43	2.11	42	2.69	59	0.72	56	2.18	28	1.24	29	2.43

	Food intake (g/bird d)				Lysine intake (mg/bird d)			
Diets	Wheat	SE	Maize	SE	Wheat	SE	Maize	SE
1	158	4.28	158	4.16	1310	8.90	1139	6.80
2	157	3.10	159	4.09	1037	21.3	922	2.12
3	158	0.74	156	1.80	790	3.66	669	15.1
4	154	4.66	157	0.53	508	8.46	441	18.6
5	128	5.41	128	4.32	218	9.19	180	6.05
6	133	5.06	125	6.70	253	9.61	199	10.7

There were significant differences in all the means of the response variables when they were compared all at once (P<0.01). These results are given in Table 2.4 . Blocking had no significant effect on the means of the response variables.

2.3.2 Mortalities

Thirteen out of 468 birds (2.8%) died during the experimental period. Mortalities were randomly distributed between treatments.

2.3.3 Responses

Individual results of broiler breeder hens to food intake, rate of lay, lysine intake, egg weight, egg output and body weight were grouped according to dietary treatments and are presented in Appendix 1.

The mean responses for all treatments were calculated for the final four weeks, with the main effects of various treatments presented in Table 2.4. Treatment 6 and 12 were designed to test whether lysine was the first limiting amino acid in both the series of wheat- and maize-based diets. An analyses of variance was performed on treatment 5 against 6 and treatment 11 against 12 in order to test if there were any significant differences. The significant (P<0.05) response in egg output to diet 6 is shown to be higher (28.1 g/bird d) than that on diet 5 (26.3 g/bird d), and egg output on diet 12 (28.6 g/bird d) was significantly (P<0.01) higher than that on diet 11 (22.4 g/bird d). These results confirm that lysine was the first limiting amino acid in all the experimental diets. There were no significant differences in the treatments due to blocking.

2.3.4 Food Intake

The maximum amount of food allocated to each bird every day was 160g. Birds on the lowest concentration of lysine did not consume the allotted amount. The amount of food consumed decreased with birds on high lysine concentration consuming almost all the feed (158 g) and birds on treatments with low lysine concentration, consuming approximately 125 g of food. Food intake started decreasing at approximately 3.3 g/kg of lysine in the diet. When the food intake results were compared for adjacent treatments there were no significant differences in food intake for both wheat and maize based diets.

2.3.5 Carcass composition

Two birds from all the treatments were sacrificed and analysed for body chemical composition. The results are presented in Table 2.5.

Table 2.5. *Mean carcass composition (%) for all treatments after freeze drying*

Lysine	Moisture		Protein		Lipid		Ash		Total	
	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize
1	60.4	62.6	16.9	17.0	18.3	17.3	2.08	2.00	97.7	98.8
2	59.3	58.9	16.3	15.7	20.0	19.9	2.31	2.29	97.9	96.8
3	59.0	61.1	16.3	15.9	20.6	17.3	2.34	2.32	98.2	96.7
4	53.6	59.1	15.7	16.1	25.6	19.6	2.63	2.28	97.5	97.2
5	57.1	55.8	16.5	16.3	19.8	21.9	2.78	2.86	96.2	96.8
6	55.9	59.3	16.2	17.1	24.3	17.5	2.81	2.76	99.1	96.7
MEAN	57.6	59.5	16.3	16.4	21.4	18.9	2.49	2.42	97.8	97.5
SE	0.79	0.76	0.31	0.38	0.85	0.68	0.27	0.26	0.49	0.45

2.3.6 Egg output – The Reading Model

Parameters used in fitting the Reading Model to wheat and maize based diets are shown in Table 2.6.

Table 2.6. *Parameters used in fitting the Reading Model to wheat- and maize-based diets separately*

Diet	σE_{max}	W	σW	r_{EW}
Wheat	20	3.62	0.362	0.00
Maize	20	3.69	0.369	0.00

σE_{max} = standard deviation of individual maxima for members of the flock

W = mean body weight of the flock

σW = standard deviation of bodyweight

r_{EW} = correlation between egg output and body weight (assumed)

When the standard deviation obtained from this experiment was used if fitting the data to the Reading Model the residual sum of square was very high, indicating a poor fit. It was then decided to use a standard deviation of 10% which was obtained from other published experiments (Bowmaker, 1986) conducted with broiler breeders in order to improve the fit of the model.

Table 2.7 shows the coefficients of egg output and body weight computed from the Reading Model. These coefficients are used in predicting the daily lysine requirement of broiler breeder hens.

Table 2.7. *Coefficients for egg output and body weight derived from the Reading Model*

Diet	'a'(Egg output)	'b' (Body weight)	E_{max}	SS
Wheat	8.44	0.01	46.51	0.03292
Maize	7.75	0.02	48.68	0.09928

E_{max} = standard deviation of individual maxima for members of the flock
SS = sums of square deviation

The equation for an individual bird derived from this experiment for wheat- and maize-based diet were:

$$\text{Lysine intake (mg/bird d), wheat} = 8.44\ E + 0.01\ W$$

$$\text{Lysine intake (mg/bird d), maize} = 7.75\ E + 0.02\ W$$

Where E = egg output, g/bird d; and W = body weight, kg/bird.

2.4 Discussion

In major poultry producing countries either wheat or maize form a significant proportion of poultry diets. This trial was undertaken to compare the response of broiler breeder hens fed either of these ingredients in the diet with lysine as the first limiting amino acid. It is universally accepted that wheat contains more lysine than compared to maize. The diets formulated were designed to contain the same amount of lysine, but the wheat based diet ended up containing more lysine than the maize based diet (8.3 vs 7.2g/kg). As the graded levels of these diets were fed to the birds, it was expected that wheat based diets would give a better performance since the diet had a higher lysine concentration than maize based diet. However treatment 7 (highest lysine intake) had a higher non significant egg output than treatment 1 (wheat) (49.2 vs 46.6). For the wheat-based diet lysine intakes greater than 790 mg lysine/ day, did not increase egg output even when lysine content of the diet was increased further. On the other hand, as the lysine content of the maize based diet was increased from 669 to 922 mg/bird day, egg output increased from 47.0 to 48.9 g/day but these differences were not statistically significant (P=0.84). The optimum lysine level for a maize based diet was reached at 669 mg/bird day. From these results, the lysine requirement for optimum production is lower for a maize based diet compared to a wheat based diet. If synthetic amino acids are not going to be utilized, then less maize will be required in the diet compared to wheat, to meet the requirements for lysine. Breeders on maize based diets were more efficient than birds on wheat based diets. The cause of differences in performance from these ingredients can be attributed to the lysine digestibility. Table 2.3 clearly shows that wheat has a lower apparent digestibility coefficient for lysine than maize (47.93 vs 89.75%). From these results it is clear that hens on maize based diets had more lysine available to them than breeders on wheat based diets thus making them more efficient than birds from wheat based diet. The digestibility coefficients obtained from these results are in contrast to the ones obtained by Green *et al.* (1987) where he suggested the digestibility coefficients of 49.75 and 38.31 for wheat and maize respectively.

By fitting the Reading Model to the data, the coefficients of response were 8.44E and 7.75E for egg output and 0.01W and 0.02W for body weight, respectively. These coefficients were considerably lower than values previously published for broiler breeders. The coefficient for body weight suggested that almost all the lysine consumed was used for egg output. It has been clearly established with laying hens that not all the amino acid will go to egg production. The bird will first meet its maintenance requirement before production requirement. In a trial reported by Bowmaker and Gous (1991) they found the maintenance coefficient of broiler breeders to be 11.2. Subsequently it was then decided to calculate the *a* coefficient assuming a '*b*' coefficient of 10, based on the coefficient of 11.2 that was obtained by Bowmaker (1986) with broiler breeders of almost the same age. The *a* coefficient were calculated for each treatment as: $a = (I - 10W)/E$. These results are shown in Table 2.8. The overall *a* coefficient was then recalculated assuming the *b* coefficient to be 10. The calculated *a* coefficient was 15 and 13 for wheat and maize respectively. These calculated coefficients were closer to the values published by Goddard (1997).

Table 2.8. *Calculated values of the 'a' coefficient for all the treatments*

Lysine	*a* coefficient	
	Wheat	Maize
1	27	22
2	22	18
3	16	13
4	12	10
5	7	7
6	8	6
MEAN	15	13
SE	0.07	0.06

It was further decided to calculate the *b* coefficients using an assumed *a* coefficient which was published by McDonald and Morris (1985), these results are shown in Table 2.10.

The average broiler breeder hen of 3 kg, producing 45 g of egg output per day would need 380 mg of lysine daily if fed a wheat based diet and 349 mg of lysine if fed a maize based diet.

Since the calculated *a* coefficients (15 and 13) took into account maintenance requirements, it was then agreed to use them in calculating the efficiency of lysine utilization. The '*a*' coefficient of the Reading Model, which determines the slope of the line above maintenance and is expressed as mg lysine per g egg, was 8.44 and 7.75 for wheat- and maize-based diets respectively. The egg was assumed to contain 8.3 mg lysine per gram (Fisher, 1994). The efficiency coefficient was 0.98 and 1.07 for wheat- and maize-based diets respectively. Birds laying below 0.5 were subsequently removed from the analyses and the data was reanalysed (Table 2.9).

Table 2.9. *Mean responses in egg output (observed and estimated) to lysine from wheat- or maize-based diets, from which birds laying fewer than 14 eggs in 28 days were excluded*

Lysine intake (mg/bird d)	Observed egg output (g/bird d)	Estimated egg output (g/bird d)
Wheat		
1308	47.7	47.1
1043	48.4	47.1
789	48.1	47.1
505	42.8	46.4
210	31.0	29.5
255	35.1	35.4
Maize		
1138	50.5	46.8
922	49.0	46.8
669	47.7	46.8
441	40.5	46.8
190	38.5	36.7
240	40.7	43.2

The data from Table 2.9 was fitted into the Reading Model. The derived *a* coefficient was 7.08 for wheat-based diet and showed an efficiency of 1.17. The *a* coefficient for maize-based diet was 5.03 with an efficiency coefficient for lysine of 1.65. These coefficients imply that after birds have obtained the amino acids from the feed they also draw some extra amino acids from their body and use them for egg production. Since this is not true the efficiencies of lysine utilization were recalculated using values derived from Table 2.8. The efficiency of lysine utilization for wheat and maize were 0.55 and 0.64, respectively. These values were closer to those previously published by Goddard (1997). Broiler breeder hens laying in closed cycles should be as efficient as laying hens in converting amino acid to egg output. Bowmaker and Gous (1991) suggested an efficiency of 0.47, when not all the birds were laying in closed cycles (<0.5). When birds that were laying below 0.5 were removed from the analyses the efficiencies increased to 0.57.

In Figure 2.1 egg weight and rate of laying were plotted against lysine intakes. Instead of using actual weights and rate of lay they were expressed as proportions of the maximum egg weight and maximum rate of lay achieved in the experiment. Lysine intake was expressed as a proportion of lysine required for maximum egg output. The values are averaged over the response to lysine.

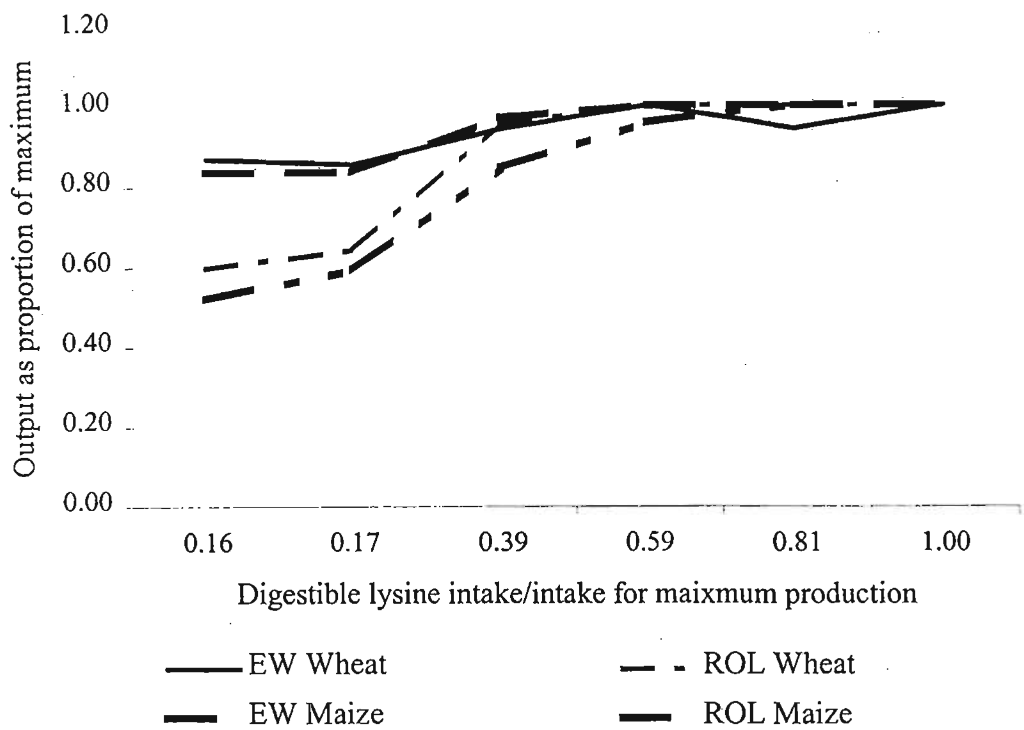

Figure. 2.1. - Relative effects on egg weight and rate of lay of a decrease in the lysine intake of broiler breeder hens. EW= egg weight and ROL= rate of lay.

Results from this experiment for egg weight and rate of lay showed that the two variables appear to be affected to the same extent until amino acid supply is reduced to 0.4 of that required for maximum output. This value is similar to the one observed from the experiment with older birds. As the amino acid was reduced further, rate of laying declines almost linearly to a low of 0.5 of the maximum, whereas egg weight reached a minimum size of 0.8 of the maximum, as illustrated by Figure. 2.1. These values are very close to those published by Morris and Gous (1988) for laying hens and Bowmaker and Gous (1991) for broiler breeder hens.

Because broiler breeder hens have considerable lipid reserves, and because it can be argued that there is no energy cost of maintaining such lipid reserves (Emmans and Oldham, 1989), it is likely that amino acid requirement for maintenance (as defined by the *b* value of the Reading Model) over different types of poultry would be more closely related to body protein content than to body weight. A more accurate estimate of the amount required for maintenance, when comparing laying hens of different size and body composition would therefore be that related to the protein content of the body (Emmans and Fisher, 1986). It was decided to compare maintenance requirements, based on bodyweight or lipid free bodyweight.

The amount of lysine required for maintenance of bodyweight was calculated as (amino acid intake – *a*E)/W, also as (amino acid intake – *a*E)/LFBW. Maintenance body protein was calculated as 0.008 $BP_m^{0.73}$ × 75 mg lysine/g protein (Fisher, 1986), for all the treatments. The amount of lysine required per kg of body weight was calculated assuming an *a* value of 10 mg/ g egg for lysine.

Table 2.10. *Lysine maintenance requirement obtained from using different parameters*

Lysine	mg lysine/g Bodyweight		mg lysine/g LFBW		mg lysine/ g BP	
	Wheat	Maize	Wheat	Maize	Wheat	Maize
1	220	165	228	168	68	69
2	154	112	157	118	67	65
3	84	54	87	57	66	65
4	30	19	34	20	61	63
5	14	31	15	32	58	60
6	28	40	30	41	58	63
MEAN	88	70	92	73	63	64
SE	0.76	0.63	0.77	0.63	0.38	0.14

Because a number of treatments with high concentration of lysine supplied many of the birds on those treatments with excessive amounts of lysine, and similarly a number of limiting treatments caused poor production, treatment 3 and 9 appeared to be reasonable estimates of the marginal response to lysine when using bodyweight and LFBW as prediction parameters. There were significant differences ($P<0.05$) in results obtained from adjacent treatments of wheat and maize. When body protein content was used there were no significant differences (66 vs 65). Lysine maintenance requirements are a function of bodyweight and the level of production of the bird.

CHAPTER 3

RESPONSE OF 52 TO 62 WEEK OLD BROILER BREEDER HENS TO DIETARY LYSINE AT DIFFERENT DIETARY ENERGY LEVELS

3.1 Introduction

The amino acid requirement of broiler breeder hens, as determined empirically, varies over a wide range. This variation results from differences in body size, feed consumption, egg production and egg weight among the experimental birds used by various investigators, due to differences in breed, age and diet. Efficiency of amino acid utilization for egg production varies with rate of lay. When rate of lay is above 0.5, efficiencies range between 0.8 and 0.85, but when rate of lay is zero the efficiency also becomes zero. The latter implies that the efficiency of amino acid utilization may also be a possible cause of the variation in amino acid requirements. It must, therefore, be accepted that no single requirement for any amino acid really exists for broiler breeder hens, but that it changes with the determinants of requirement.

Changes in dietary energy concentration modulate feed efficiency through two partially dependent pathways. Firstly, as dietary energy increases, energy needs are satisfied with decreasing feed intake; secondly, growth rate is promoted by increasing dietary energy content, provided that no other nutrient is limiting. This was also confirmed by Gous *et al.* (1987) using layers. Gous and Bowmaker (1986) reported that the protein content of the feed affects the efficiency with which a bird utilizes dietary energy for the purposes of egg production and tissue formation.

The purpose of this experiment was to determine the response in egg output to lysine intake and to determine whether the response differs when the energy content of the diet is varied.

3.2 Materials and methods

3.2.1 Birds and management

Three hundred Ross broiler breeder hens, aged 52 weeks were housed in a controlled environment house. Each hen was kept individually in a wire cage (55 cm high, 40 cm wide and 45 cm deep) , equipped with two nipple drinkers with drip cups, and a feeder (15cm wide, 13cm deep). The house was cross-ventilated with six fans; light-tight due to baffles over the fan openings and insulated. The lighting regime used throughout the experiment was 16L : 8D. The experiment was conducted for ten weeks, ending when the hens were 62 weeks of age. Prior to the start of the experiment, all birds had been kept on a restricted feed schedule, being fed 150g/bird d of a commercial broiler breeder feed (14% protein; 11.7 MJ AME/kg feed).

3.2.2 Experimental design

The experiment was designed as a factorial, with lysine at six levels and metabolisable energy, at two levels, constituting the factors. Each treatment was assigned to 25 birds, with body weight being used as a blocking factor.

3.2.3 Dietary treatments

During the experimental period (10 weeks), the hens were fed one of twelve dietary treatments limiting in lysine, six diets having a high energy content (12.5 MJ AME/kg feed) while the other six had a low energy content (11.5 MJ AME/kg feed). . The diets were mixed by diluting two concentrated (summit) mixtures with two (practically) protein-free dilution mixtures (Table 3.1) according to the technique described by Fisher and Morris (1970) modified by Pilbrow and Morris (1974). The summit diets were designed to supply approximately 1350 mg lysine/bird at an intake of 150g/bird d. This intake of lysine was calculated to provide approximately 1.2 of the requirement for lysine of a 3.1 kg broiler breeder hen producing 70 g egg output/d, based on coefficients of response published by McDonald and Morris (1985). Requirements for all other amino acids were calculated in a similar manner, the amounts in the summit diet providing a minimum of 1.4 of the requirement for each amino acid other than lysine.

The summit diets and the dilution diets were analysed for protein, amino acids, calcium and phosphorus content (Table 3.1).

Table 3.1. *Chemical composition (g/kg) of the summit and dilution diets on as fed basis*

Ingredients	Summit 1	Dilution 1	Summit 2	Dilution 2
Yellow Maize	460	-	420	-
Wheat Bran	10.0	-	-	-
Sunflower 37	150	-	150	-
Soyabean 48	99.6	-	110	-
Sunflower oil	-	60.0	40.0	100
Sodium bicarbonate	0.33	1.15	0.38	0.82
DL - Methionine	0.21	-	2.16	-
Vit+min[1]	2.50	2.50	2.50	2.50
Monocalcium Phosphate	7.84	14.0	8.49	14.0
Salt	2.84	2.95	2.97	3.28
Plasterer's sand (Filler)	-	150	-	121.7
Starch	-	265	-	272.7
Sugar	-	265	-	272.7
Sunflower husks (Filler)	-	150	-	121.7
Canola fullfat	100	-	100	-
Lupin	50.0	-	50.0	-
Fish meal 65	29.8	-	26.5	-
Limestone	86.8	89.4	87.0	90.6
Analysis	**Actual**	**Actual**	**Actual**	**Actual**
AME (MJ/kg)	11.1	10.6	13.0	11.2
Crude protein (N×6.25)	195	11	192	8
Lysine	7.72	-	9.42	-
Methionine	3.88	-	5.12	-
Threonine	5.50	-	6.53	-
Tyrosine	4.64	-	6.68	-
Arginine	12.7	-	12.9	-
Histidine	4.53	-	4.86	-
Isoleucine	7.96	-	8.57	-
Phe+ Tyr[2]	12.7	-	13.1	-
Valine	9.08	-	9.16	-
Calcium	45.1	43.4	45.4	43.3
Available Phosphorus	6.10	2.70	6.0	2.60

[1] Standard commercial breeder vitamin and mineral premix.
[2] Phenylalanine + tyrosine

AME value was corrected to zero N retention and to reflect an intake of 80 g/d ($AMEn^{80}$). Protein was measured as nitrogen × 6.25, after determining nitrogen content with the LECO Nitrogen Analyser (combustion process). Amino acids were determined via high sensitivity protein hydrolysate analyses with a Beckman amino acid analyser. The procedures for AME, protein and amino acid analyses have been more fully described earlier (chapter 2, page 28-29). Calcium and phosphorus were determined by the analytical methods of AOAC (1990).

The mixing of the summit and dilution diets and subsequent blending took place at the research farm in 500 kg batches for summit and 450 kg for dilution diets (Table 3.2).

Table 3.2. *Blending proportions of the summit and dilution diets on as fed basis, to produce the experimental diets*

Feed no.	Energy Content	Lysine as proportion of requirement	Other amino acids as proportion of requirement	Summit (S) (%)	Dilution (D) (%)
				S1	D1
1	11.09	1.30	1.40	100.0	0.0
2	11.00	1.04	1.12	80.0	20.0
3	10.90	0.78	0.84	60.0	40.0
4	10.80	0.52	0.56	40.0	60.0
5	10.70	0.26	0.28	20.0	80.0
6[1]	10.70	0.76	0.28	20.0	80.0
				S2	D2
7	12.97	1.53	1.60	100.0	0.0
8	12.60	1.22	1.28	80.0	20.0
9	12.30	0.92	0.96	60.0	40.0
10	11.90	0.61	0.64	40.0	60.0
11	11.60	0.31	0.32	20.0	80.0
12[1]	11.60	0.84	0.32	20.0	80.0

[1] 0.5% lysine added as 78.4% lysine-HCl.

S1 = Summit diet for low energy series; S2 = Summit diet for high energy series

The micronutrients used were premixed by Nutrex, Pietermaritzburg. Feeds 6 and 12 were made by supplementing each of Feed 5 and 11 with 5g lysine/kg, in order to confirm that lysine was the most limiting amino acid in the basal feed.

3.2.4 Allocation of diets

Daily food allocation (150 g/bird) was measured into plastic-coated cardboard containers up to 8 d before being fed to the hens. Feeding took place at the same time each morning.

3.2.5 Measurements

Bodyweight, food intake, egg numbers, egg weight, mortalities, chemical composition of the body and lipid free body weight were measured as in Chapter 2.

3.2.5.1 Egg components

Thirty eggs from each treatment were collected during the last three days of the trial. The eggs were weighed, broken out and the yolks and albumens separated. The yolks were then weighed, and the shells were dried in a force-draught oven for 12 hours at 60°C before being weighed. Albumen weight was calculated by subtracting yolk weight and dry shell weight from egg weight. This was done to determine whether the dietary treatments influenced the proportions of yolk and albumen in the egg.

3.2.6 Statistical Analyses

An analysis of variance was performed on the data using a general linear model to test for significance between treatment means over the final four weeks of the experiment and to test whether blocking had any effect. The independent variables used were energy and lysine level . Interaction between the two factors was tested. The response variables measured were the same as the one measured in chapter 2, except that energy intake was also measured. Data from this period were used on the assumption that by this time the response of the birds to the treatments would have stabilised. Birds from the last block (13) were not included as part of the analyses when the means were computed, as they caused the experimental design to be unbalanced. This is due to only block 13 having only one treatment appearing in it instead of two like other blocks. Only two hundred and eighty eight birds were therefore used in computing the means. The results from all surviving birds were used to perform regression analyses on the data. Minitab (1998) was used for statistical analyses.

3.3 Results

3.3.1 Experimental diets

The analyses of the12 experimental diets revealed that there were not two distinct energy levels as planned, but rather each treatment had a different energy level which decreased with the lysine content of the treatments. The lysine and energy concentration of the 12 diets are shown in Table 3.3. It can be seen that the energy levels were lower for diets 1 to 6 compared to diets 7 to 12. Hence, two energy series emerged, a lower- and a higher energy series.

Table 3.3. ***The lysine and energy concentrations of the 12 experimental diets on as fed basis***

Diet	Energy series	Lysine concentration (g/kg)	Energy concentration (MJ/kg)
1	Lower	7.70	11.1
2	Lower	6.20	11.0
3	Lower	4.60	10.9
4	Lower	3.10	10.8
5	Lower	1.50	10.7
6	Lower	3.50	10.7
7	Higher	9.40	13.0
8	Higher	7.50	12.6
9	Higher	5.60	12.3
10	Higher	3.80	11.9
11	Higher	1.90	11.6
12	Higher	3.90	11.6

An essential prerequisite of any response trial is to confirm that the nutrient being studied is limiting in the diets used. In this experiment, treatments 6 and 12 were designed to test whether the series of diets 1 to 5 and the series of diet 7 to 11 were first limiting in lysine. The compositions of diets 6 and 12 were the same as those of diets 5 and 11 respectively, except that an amount of L-lysine HCL was added that would result in diet 6 and 12 having a higher lysine content than diet 5 and 11 (Table 3.2). In Table 3.5, the response in egg output to diet 6 is shown to be lower (12 g/bird d) than that on diet 5 (14 g/bird d), and egg output on diet 12 was lower than on diet 11 (11 vs 14 g/bird d). From these results lysine could not be confirmed to be the first limiting nutrient in either dilution series. Egg weight was higher on diet 6 than on diet 5 (63 vs 58 g/bird d) and also on diet 12 than on diet 11 (63 vs 57 g/bird d). The possible reason as to why egg output could not demonstrate that lysine was the most limiting nutrient in the diet was due to the fact that too much lysine was added to treatment 6 and 12 and birds on these treatments responded by reducing food intake and subsequently stopped laying. The energy content of these treatments had no effect since it was identical. The average treatment means from week to 4, 5 and 6 were analyzed and are given in Table 3.4. From these results it is clear that lysine is the most limiting amino acid in the diet but this effect diminished after the overall average of week 6 due to the fact that birds were starting to show that there was too much lysine supplemented in the demonstration diets, thus resulting into depressed food intake with a consequent of reduced amino acid intake.

Table 3.4. *Mean response in egg output (g/bird d) to lysine with the means of 4, 5 and 6 weeks respectively.*

Week	Treatment 5	Treatment 6	Treatment 11	Treatment 12
4	24.9	29.6	24.9	28.2
5	22.9	24.9	21.5	23.8
6	20.7	20.9	18.9	20.8
SEM	0.06	0.06	0.06	0.06

3.3.2 Mortalities

Seven out of 300 birds (2.3%) died during the experiment. The mortalities were randomly distributed between the treatments.

3.3.3 Responses

The individual results for broiler breeder hens of body weight, change in body weight, rate of lay, egg weight, egg output, food intake, lysine intake and energy intake were grouped according to dietary treatment and are presented in Appendix2. The mean response for all treatments was calculated for the final four weeks of the experiment. Blocking had significant difference on final body weight (P<0.01), but there were no significant differences on change in BW (P=0.13), ROL (P=0.40), EW (P=0.97, EO (P=0.47), FI (P=0.62), lysine intake (P=0.96) and energy intake (P=0.62).

Table 3.5. *Treatment responses of the variables measured, due to main effects (Metabolisable energy & lysine) over the final four weeks of the experiment*

	Bodyweight (g)			Change in body weight (g)		
Lysine	LE	HE	Mean	LE	HE	Mean
1	3510	3761	3635	1.7	6.6	4.2
2	3578	3827	3703	2.8	7.3	5.1
3	3519	3769	3644	1.4	6.8	4.1
4	3299	3379	3339	0.1	-1.1	-0.5
5	2883	2569	2726	-5.2	-25.7	-15.5
6	2784	2369	2576	-8.2	-28.7	-18.5
	3262±32	3279±67	3271±57	-1.2±0.7	-5.8±0.7	–1.2±0.7

	Rate of lay %			Egg weight (g/bird d)			Egg output (g/bird d)		
Lysine	LE	HE	Mean	LE	HE	Mean	LE	HE	Mean
1	63	62	62	68	70	69	42	43	43
2	60	61	60	70	68	69	42	42	42
3	62	64	63	68	68	68	42	44	43
4	59	57	58	66	63	64	38	36	37
5	23	23	23	58	57	58	13	14	14
6	23	17	20	63	63	63	12	11	13
	48±1	47±1	48±2	65±1	65±1	65±1	32±1	32±1	32±1

	Food intake (g/bird d)			Lysine intake (mg/bird d)		
Lysine	LE	HE	Mean	LE	HE	Mean
1	149	148	148	1147	1388	1267
2	149	147	148	916	1102	1009
3	148	145	147	683	819	751
4	147	146	146	451	549	500
5	110	71	90	166	119	143
6	92	62	77	167	120	144
	132±1	120±2	126±3	588±4	683±4	635±6

	Energy intake (kJ/bird d)		
Lysine	LE	HE	Mean
1	1653	1919	1786
2	1636	1852	1744
3	1612	1784	1698
4	1583	1742	1662
5	1179	816	997
6	983	719	851
	1441±16	1472±1	1457±28

HE = high energy, LE = low energy.

Results from Table 3.5 for all the treatments means derived from the variables measured in the final 4 weeks of the trial showed significant differences ($P<0.01$). When the main effects were considered lysine had significant differences ($P<0.01$) for all the variables measured. Energy content of the diet had a significant effect on lysine intake ($P<0.01$) and final BW ($P<0.05$), there were no significant differences for FI ($P=0.08$), EO ($P=0.78$), EW ($P=0.82$), ROL ($P=0.77$) and change in BW ($P=0.77$). Birds on low energy diets consumed more food with less lysine, whist birds on high energy level treatments consumed less food with high levels of lysine concentration.

3.3.4 Food intake

The maximum amount of food allocated to the birds each day was 150g. Birds on the lowest concentrations of lysine did not consume the allotted amount. The amount of food consumed decreased from the maximum of 150g to approximately 70g. Food intake started decreasing at approximately 3.8 g/kg of lysine in the diet.

3.3.5 Egg output – The Reading Model

The parameters used in fitting the Reading Model to each of the high and low energy series and parameters for a common curve are shown in Table 3.6.

Table 3.6. *Parameters used in fitting the Reading Model to low and high energy treatments separately, and combined*

Energy	σE_{max}	W	σW	r_{EW}
Low	10	3.26	0.33	0.00
High	10	3.27	0.33	0.00
Combined	10	3.27	0.33	0.00

σE_{max} = standard deviation of individual maxima for members of the flock

W = mean body weight of the flock

σW = standard deviation of bodyweight

r_{EW} = correlation between egg output and body weight (assumed)

Table 3.7 shows the coefficients of egg output and bodyweight computed by the Reading Model. These coefficients may be used to predict the daily lysine requirement of broiler breeder hens.

Table 3.7. *Coefficients for egg output and body weight derived from the Reading Model*

Energy level	'a'(Egg output)	'b' (Bodyweight)	E_{max}	SS
High	9.29	0.01	42.40	0.03767
Low	10.23	4.57	42.69	0.00550
Combined	9.41	0.00		0.06205

E_{max} = maximum potential egg output of the flock (estimated by Reading Model)

SS = sum of squares deviation

The equation for an individual bird derived from this experiment was:

$$\text{Lysine intake (mg/bird d)} = 9.41\ E + 0.00\ W$$

Where E = egg output, g/bird d and W = body weight, kg/bird.
The average broiler breeder hen of 3 kg, producing 45 g of egg output per day would need 423 mg of lysine daily.

Since the results from the Reading Model imply that all the amino acid intake go to egg production it was then decided to calculate the *a* coefficient assuming a '*b*' coefficient of 10. The *a* coefficient was calculated as: $a = (I - 10W)/E$. These results are shown in Table 3.8.

Table 3.8. *Calculated value of the 'a' coefficient for all the treatments*

Lysine	*a* coefficient	
	LE	HE
1	26	31
2	21	25
3	15	18
4	11	14
5	11	8
6	11	10
MEAN	16	18
SE	0.42	0.50

LE = Low energy; HE = High energy

The calculated *b* coefficients are shown in Table 3.11.

3.3.6 Calculating yolk and albumen proportion of the eggs

In order to test whether dietary treatments influence the yolk and albumen proportion of the egg, proportions were calculated for yolk, albumen and shell weight for all the treatments. There were no significant differences in the proportions due to treatments. Table 3.9 gives the overall mean proportions for the eggs.

Table 3.9. *Mean proportions of egg components (yolk, albumen and shell)*

Lysine	Yolk^{P}		Albumen^{P}		Shell^{P}	
	LE	HE	LE	HE	LE	HE
1	0.32	0.31	0.59	0.60	0.09	0.09
2	0.32	0.32	0.59	0.59	0.09	0.09
3	0.32	0.33	0.59	0.59	0.09	0.08
4	0.40	0.31	0.48	0.60	0.12	0.09
5	0.29	0.30	0.63	0.63	0.08	0.07
6	0.33	0.29	0.58	0.63	0.09	0.08
MEAN	0.33	0.31	0.61	0.61	0.09	0.08
SE	0.03	0.02	0.04	0.02	0.02	0.02

LE = Low energy; HE = High energy
P = proportion

3.3.7 Efficiency of lysine utilization

In order to test the hypothesis that broiler breeders laying in closed cycles have the same net efficiency of utilization of lysine for egg production as do laying hens, a subsequent analysis was performed in which data from all birds laying fewer than 14 eggs in the final

28 d period were excluded from the analyses. Since treatment 5, 6, 11 and 12 did not meet this criterion, only 8 means could be calculated this way. These means are given in Table 3.10.

By fitting the Reading Model to these combined data, the *a* coefficient increased from 9.41 to 11.37 mg lysine/ g egg output, but when the data was fitted individually for different energy levels, the *a* coefficient decreased slightly from 10.23 to 10.13 for low energy series and for the high energy series it also decreased from 9.29 to 1.75. The *b* coefficient did not change it remained as zero. The increase in the *a* coefficient from a combined data was caused by an increase in the residual sum of square when the data was pooled together (Table 3.7). Assuming that the egg contains 8.3 mg lysine/g egg this adjusted *a* coefficient implies an efficiency of lysine utilization for egg production of 0.73. When the calculated mean *a* coefficient was used the efficiency of lysine utilization became 0.49.

Table 3.10. *Observed and estimated responses in egg output to lysine at different energy levels excluding data from birds laying fewer than 14 eggs in 28 days*

Lysine intake (mg/bird d)	Observed egg output (g/bird d)	Estimated egg output (g/bird d)
Low energy		
1146	43.3	43.4
917	43.5	43.4
683	43.3	43.3
450	40.0	40.0
High energy		
1388	46.4	46.2
1116	45.1	46.2
819	47.2	46.2
551	39.0	39.0

3.3.8 Maintenance requirement for lysine

The amount of lysine required for maintenance of bodyweight was calculated as (amino acid intake – aE)/W, also as (amino acid intake – aE)/lipid free bodyweight (LFBW). Maintenance body protein for lysine was calculated as 0.008 $BP_m^{0.73}$ × 75mg lysine/g protein, for all the treatments. The amount of lysine required per kg of bodyweight was calculated assuming an a value of 10 mg/ g egg for lysine.

Table 3.11. *Lysine maintenance requirement calculated from using different prediction parameters*

Lysine	mg lysine /g BW		mg lysine/g LFBW		mg lysine/ g BP	
	LE	HE	LE	HE	LE	HE
1	207	255	279	269	56	53
2	139	178	137	194	59	55
3	75	101	78	113	60	52
4	22	56	25	60	43	49
5	14	-3	14	-3	37	36
6	14	8	16	10	42	46
MEAN	79	99	92	107	50	49
SE	0.74	0.84	0.85	0.86	0.26	0.22

Because a number of treatments with high concentration of lysine supplied many of the birds on those treatments with excessive amounts of lysine, and similarly a number of limiting treatments caused poor production, treatment 3 and 10 appeared to be reasonable estimates of the marginal response to lysine when using body weight and LFBW as prediction parameters, as can be seen from Table 3.11. When maintenance requirements were related to body protein, the overall mean maintenance requirement for low energy and high-energy series were found to be 60 and 52 mg lysine/g protein day respectively.

3.3.9 Carcass composition

The carcass composition of birds on all the treatments are shown in Table 3.12.

Table 3.12. *Results of carcass composition (%) analyses across all treatments after freeze drying*

Lysine	Moisture		Protein		Lipid		Ash		Total	
	LE	HE	LE	HE	LE	HE	LE	HE	LE	HE
1	62.15	57.40	13.51	13.29	16.42	23.60	2.84	2.76	94.92	97.04
2	61.28	63.27	13.64	14.25	16.45	15.55	2.57	2.88	94.24	95.94
3	57.82	61.34	12.97	14.64	21.62	15.30	2.61	2.96	95.03	94.24
4	54.46	53.47	12.57	10.45	20.57	25.61	4.09	2.09	91.69	91.62
5	60.60	52.37	9.69	11.58	20.38	26.76	2.51	3.09	93.18	93.79
6	60.11	62.30	15.85	14.53	14.94	14.54	3.38	2.78	94.27	94.15
MEAN	59.40	58.36	13.04	13.12	18.40	20.23	3.05	2.76	93.89	94.46
SE	0.14	0.18	0.12	0.11	0.14	0.20	0.08	0.05	0.09	0.11

3.4 Discussion

Egg output increased with increasing lysine intake throughout the range of treatments applied, although the rate of increase diminished at the highest lysine intakes. At highest dietary lysine concentrations birds consumed virtually all of their daily food allowances on both energy series. At each lysine concentration, birds on the high-energy series consumed less food than those on the lower energy series. At marginal levels of dietary lysine, birds reduced their rate of lay in both energy series, suggesting that rate of lay is affected more by lysine content of the diet than the energy content of the diet. The curves derived from the Reading Model for both energy series had the same shape. Birds on food with lysine concentration above approximately 3 g/kg on high-energy content gained more weight and deposited more fat than birds on low energy content. However in general birds on high energy content ate less food than birds on low energy content although these differences were not significant. There were no significant differences in rate of lay from adjacent lysine treatments in either energy series. From these results there was no evidence to suggest that an interaction between lysine and energy occurred. The interaction only seem to occur at marginally low levels of lysine; these appear to be highly correlated and cannot be assumed to act independently.

The *a* coefficient (9.41) derived when using the Reading Model is lower than the value published by Goddard (1997) for broiler breeders of 60 weeks of age (12.19). Because the Reading Model estimated the *b* coefficient to be zero, it was decided to recalculate the *a* coefficient, assuming the *b* coefficient of 10. The mean *a* coefficient thus calculated was 17. All the coefficients for maintenance *b* determined in this experiment were similar to the coefficient derived by Goddard (1997) for older broiler breeders. Maintenance requirement was compared using body weight or LFBW. From the results obtained, there were no significant differences from using either or, of these parameters. When the maintenance requirement was related to body protein, the mean maintenance requirement was 60 and 52 mg lysine/g body protein for low and high energy diets. Birds on good treatments increased their body weights, especially birds from high-energy series when compared to birds from low energy series. This increase in body weight was in lipid form. When the maintenance requirement were estimated using body weight as a prediction parameter birds on high energy content had significantly ($P<0.05$) higher requirements than birds from low energy content from adjacent treatments provided lysine was high. These requirements seem to be over estimated for heavier birds and underestimated for light birds. This is because there is no nutritional cost in maintaining lipid reserves. When the same comparison was made using body protein content as a maintenance prediction parameter, there was no significant difference in maintenance requirements for birds from adjacent treatments.

In Figure 3.1 egg weight and rate of laying were expressed as proportions of the maximum egg weight and maximum rate of lay achieved in the experiment; and lysine intake was expressed as proportion of lysine required for maximum egg output. The values are averaged over the response to lysine as in the experiment with younger broiler breeder hens reported in chapter 2.

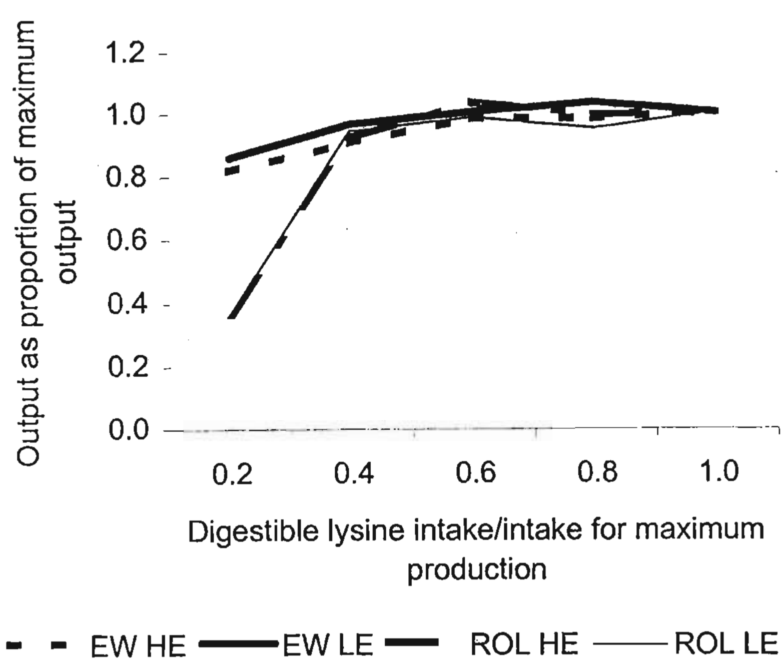

Figure. 3.1. - Relative effects on egg weight and rate of lay of a decrease in the lysine intake of broiler breeder hens. EW= egg weight, HE= high energy, LE= low energy and ROL= rate of lay.

In a summary of a number of trials in which laying hens had been subjected to a range of diets differing in amino acid content, Morris and Gous (1988) showed that egg weight and rate of laying were equally reduced at marginally deficient amino acid intakes, but as the deficiency became severe, rate of laying was reduced to a greater extent than was egg weight. Bowmaker and Gous (1991) conducted the same exercise and observed that the effect of a reduction in amino acid supply on rate of laying and egg weight is the same for broiler breeder hens as it is for laying pullets. Results from the present experiment show that the two variables appear to be affected to the same extent until amino acid supply is reduced to 0.4 of that required for maximum output, whereas Bowmaker and Gous (1991) reported 0.64. As the amino acid was reduced further, rate of laying declines almost linearly to a low 0.38 of the maximum, whereas egg weight reached a minimum size of 0.8 of the maximum, as illustrated by Figure. 3.1. These values are similar to those obtained from the first experiment and previously published for laying pullets and broiler breeder hens.

An efficiency of between 0.75 and 0.85 was suggested by McDonald and Morris (1985) and by Emmans and Fisher (1986) for laying hens, Bowmaker and Gous (1991) suggested an efficiency of 0.47 for broiler breeder hens. Again in this experiment like the experiment with younger broiler breeder hens reported on earlier, it was decided to use the calculated *a* coefficient for obtaining the efficiency of lysine utilization since maintenance requirement was considered when calculating the coefficient. The efficiency of lysine utilization was 0.49, which is lower than the value (0.68) obtained by Goddard (1997) for broiler breeders of 60 weeks of age.

Broiler breeder hens laying in closed cycles should be as efficient as laying hens in converting dietary amino acid to egg output. When this hypothesis was tested using the *a* coefficient derived from the Reading Model, the efficiency decreased instead of increasing, from 0.88 to 0.73. There was too much variation in the egg output from the high-energy series data which led to the *a* coefficient increase when the data from both energy series was pooled. When the data was split apart in both low and high-energy series the *a* coefficient was reduced from 10.23 to 10.13 and 9.29 to 8.75, respectively. These results imply that before the data was split broiler breeders required 10.23 and 9.29 mg of lysine to produce 1g of an egg for low and high energy series. Later when the data was split these values became even less, implying that broiler breeders required less amount of lysine to produce 1 g of an egg, thus it was concluded that the efficiency improved. These coefficients only serve to demonstrate that the efficiency improves with rate of lay. Since the model did not take into account maintenance requirement, it can be argued that all the efficiencies were slightly overestimated.

CHAPTER 4
GENERAL DISCUSSION

The main objectives of this study were to (i) compare the response of broiler breeder hens to dietary lysine at peak and late in the laying cycle, (ii) to compare the coefficients of response to those previously published, (iii) to determine whether there is any interaction between the response to lysine and to energy, and (iv) to compare the responses to lysine when broiler breeders are fed either wheat or maize based diets.

Food allowances for breeding hens are based on expected patterns for egg production. Thus, a generous allowance early in lay is followed by a period of mild regulation over peak production, and a subsequent reduction in allowance as egg production declines in the later part of lay. Because feed allowance is varied according to the level of production, a considerable variation in daily nutrient intake occurs throughout the production cycle. This results in possible deficiencies or excesses when nutrient content of the diet is not properly adjusted to the level of feed consumption and production. Feeding graded levels of a limiting amino acid from this study has shown this. In this study, broiler breeder hens on excessive amino acid intakes did not improve their rate of laying after the optimum amount required for maximum production had been reached. On the other hand, birds on severely deficient diets responded by reducing their rate of laying, in order to meet other physiological requirements.

Two experiments were conducted in this study, with flocks of different age groups. In the first experiment, 36 weeks old broiler breeder hens were used to determine the response of these hens to dietary lysine, when feeding either a wheat- or maize-based diet. In the second experiment, 52 weeks old broiler breeder hens were used to determine whether there is any interaction between the response to lysine and energy. While the diets were designed to have either a high or low energy content for the second experiment, we ended up with a series of low and high-energy diets. For both experiments the data was fitted into the Reading Model. The following equations were derived from the model:

Experiment 1, lysine intake (mg/bird d) wheat = 9.05 E + 0.00 W
Experiment 1, lysine intake (mg/bird d) maize = 8.45 E + 0.02W
Experiment 2, lysine intake, pooled data (mg/bird d) = 11.48 E + 0.00 W
Where E = egg output (g/ bird d) and W = body mass (kg)

The average broiler breeder hen of 3 kg, producing 45 g of egg output per day would need 380, 349 and 423 mg of lysine daily, derived from wheat, maize and pooled energy series data, respectively. The coefficients of response derived from the Reading Model for this study were lower than the ones previously published thus, lowering the requirements. It is a well known factor that genetic selection and improvement techniques employed by breeding companies have improved over the years. It can be concluded these birds had lower requirements when compared to previously published data because today's birds are becoming more efficient than birds from a decade ago because of vigorous selection methods that are now employed in the industry. The other conclusions reached from these results are that, for the same amount of egg output an older bird requires more lysine than a younger bird; and birds on maize based diet were more efficient than birds on wheat based diet. Birds on maize based diets are more efficient than birds on wheat based diets because lysine digestibility (89.75 vs 47.93) is higher in maize than in wheat, thus making more lysine available to the birds. The response to lysine at different energy concentrations in egg output was such that a common curve adequately describes the response at each of the dietary energy concentrations. Egg output is therefore not influenced by energy concentration, other than through its effect on food intake, with a consequent change in intake of the first limiting amino acid. The conclusions reached from the Reading Model were that there is no interaction between the response in egg output to lysine and energy. The interaction seem to occur at lysine levels below 3 g/kg and this is caused by low lysine cont of the diet.

For both experiments the *b* coefficient derived from the Reading Model was zero. This implies that all of the lysine consumed by the broiler breeder hens is used for egg production. Biologically this is not true. In laying hens it has been established that the laying hens utilizes the amino acid firstly by meeting its maintenance requirements, before utilizing the rest for egg production. Bowmaker and Gous (1991) also demonstrated this when they were working with broiler breeders hens. They obtained a '*b*' coefficient of 11.2 for lysine. Hence, the *a* coefficients derived from both experiments with the Reading Model cannot be used to calculate the efficiency of lysine utilization. It was then decided to recalculate the *a* coefficient assuming the *b* coefficient to be 10 for both trials. The *a* coefficients thus derived were 15, 13 and 17 for wheat, maize based diets and different energy series diets from the first (young hens) and second experiment (older hens), respectively.

The Reading Model uses bodyweight to predict maintenance requirement, by deriving the *b* coefficient from bodyweight. Because broiler breeder hens have considerable lipid reserves, and it can be argued that there is no energy cost in maintaining such lipid reserves (Emmans & Oldham, 1989), then bodyweight cannot be regarded as a good predictor of maintenance requirement, as was observed from the results derived from the Reading Model in the second experiment. There were significant differences in the maintenance requirements for adjacent treatments when bodyweight was used as a predictor variable in both high and low energy content treatments. Lipid free bodyweight was then considered as a predictor variable for maintenance requirement across all treatments. There was no significant difference between the values obtained using either bodyweight or lipid free body weight across all the adjacent treatments. It was then decided to relate the amount of lysine required for maintenance to body protein content. There were no significant differences in results obtained from all adjacent treatments. It was then decided to use body protein as a maintenance prediction parameter. In the first experiment (younger hens) the average amount of lysine required for 1g of body protein was estimated to be 66 and 65 mg lysine for wheat and maize based diets, respectively. Although this values is lower than the values previously published by Fisher (1998) of 73 mg they seem reasonable enough. For the second experiment (older hens) the amount of lysine required for 1g of body protein was estimated to be 60 and 52 mg lysine for low- and high-energy based diets, respectively. The younger flock in the first experiment had a higher maintenance requirement than older flock from second experiment possible because these birds are restricted throughout their lives and might have room for growth while the older flock are nolonger growing body protein, but lipid.

In studies with laying hens it has been shown that the efficiency of utilization declines in ageing hens (Fisher and Morris, 1967; Jennings *et al.*, 1972; Wethli and Morris, 1978). Goddard (1997), working with broiler breeder hens of different age groups also concluded that the efficiencies of utilization of 53 and 65 week old birds were lower when compared to 31 and 45 weeks old birds. In a model described by Fisher (1998), amino acid utilization coefficients for egg production were considered to be related to the rate of lay and, thus, declined with the age of the flock. In calculating amino acid requirement of flocks with different ages, Gous *et al.* (2001), using Fisher's (1998) method, related efficiency of amino acid utilization to rate of lay. Using the asymptotic rates of lay observed at each age they predicted the efficiency of amino acid utilization as 0.82, 0.76, 0.58 and 0.57 for ages 26, 37, 48 and 60 weeks respectively. They further recalculated the efficiencies using an assumption that the egg contains 8.3 mg lysine per gram of egg, and using this estimates of the '**a**' coefficient they got an efficiency of utilization of 0.59, 0.58, 0.58 and 0.68 respectively (for the four age groups mentioned earlier). The mean efficiency coefficient, derived from the calculated coefficient for egg output, from the first experiment using a younger flock (36 weeks) was higher for wheat and maize based diets than (0.55 and 0.64 vs 0.49) the one derived from the second experiment with an older flock (52 weeks). The youngest birds had the highest egg output at all levels of lysine intake, than compared to older flock. Hence, it can be concluded that the efficiency for amino acid utilization declines with rate of lay as the flock ages, as is the case with laying hens. This decline in the efficiency of lysine utilization with age is due to an increase in the number of birds with rates of lay below 0.5. These results confirm the relationship that was observed by Fisher (1976 and 1980) between efficiency and rate of lay. Equations derived from the Reading Model clearly show that older birds require more lysine than younger birds for the same egg output, as was observed by Goddard (1997).

Birds in both experiments on diets with the highest lysine concentration ate all or almost all of their daily food allowances. However, as the lysine concentration of the diet decreased, to below 3.8 g lysine/kg food, the food intake decreased. Bowmaker and Gous (1991) and Goddard (1997) observed this decrease in food intake with decreasing amino acid concentration of the diet when lysine was the first limiting amino acid. The reason for decrease in food intake with decreasing lysine concentration is due to the animal's need to maintain thermal balance with the environment (Emmans, 1981). In laying hens it has been established that birds increase their food intakes as the concentration of the limiting nutrient is reduced as long as gut capacity and environment will allow this. In the second experiment (older hens), the decreasing intake was prevalent in both energy series. In the case, where lysine concentration was almost identical to adjacent treatments for the two energy series, birds fed on high-energy concentration had a lower food intake. Increasing the energy concentration of the diet decreases food intake, as was observed by Emmans (1981) and Goddard (1997).

In the light of results from this study, decreasing the food allowance after peak production is not the most ideal way to achieve maximum egg output from broiler breeder hens. Even though there is a large number of birds laying below 0.5, there are some birds laying close to 1, and these birds must not be penalized because of the presence of poor- and non-laying birds.

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APPENDIX 1

Individual response for all treatments in Chapter 2
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APPENDIX 2

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