The Effects of Dietary Lysine, Crude Protein, Energy and Feed Allocation on Broiler Breeder Hen Performance

Jamila Patel

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ABSTRACT

This study was conducted to investigate the effects of varying levels of dietary lysine and feed allocation, on the performance of female broiler breeders. In trial 1, 900 Cobb breeders from 26 to 45 weeks of age were used. The first four treatments had a fixed level of lysine throughout the experimental period, with 1200, 1070, 930 and 800 mg Lysine/bird/day and the last two treatments had their levels of lysine changed every two weeks, with treatment five started off with 1200 mg lysine/bird/day followed by a gradual decrease up to 975 mg lysine/bird/day at 45 week old, while treatment six started with the lowest level of lysine, 800 mg/bird/day and at 45 week old the intake was 1025 mg/bird/day. The rations provided 1900KJ ME/ day, the birds received 160 g of feed/day. Dietary lysine did not affect body weight, egg production, or egg composition. There were no significant differences in age at 50%, or peak production. Birds receiving 1070 and 1025 mg lysine/bird.day had a slightly, but not significantly, higher production in the current study. Birds receiving 1200 mg lysine/bird.day had the highest body weight and the lowest egg production. In trial 2, 900 broiler breeder hens were used. Protein intake and feed allocation were changed for each treatment at 26, 38 and 50 weeks and ending at 60 weeks. Birds on T1 were fed a constant CP content (145 g protein/kg) but a decreasing feed allocation (175 to 145 g/d). Those on T2 had a constant feed allocation (160 g/d) and a decreasing CP (166 to 124 g/kg) while those on T3 had varying levels of protein (166, 124 and 166 g/kg) and feed allocation (160, 160, 145 g/d). Mean cumulative protein intakes were 5.2, 5.3 and 4.8 kg/bird and mean energy intakes were 417, 412 and 402 MJ/bird for T1, T2 and T3 respectively. Body weights differed significantly at the end of the trial ($P<0.05$) with T2 showing the highest weight gain. However, egg production, egg weight and egg output were not affected by treatment. These breeders did not benefit from the additional protein and energy provided in the first and second periods by T1 and T2 (*vs*. T3), nor did they benefit from the additional energy provided in the final ten weeks of production by T2.

DECLARATION – PLAGIARISM

Jamila Patel declare that

1. The research reported in this dissertation except where otherwise indicated, is my original research.
2. This dissertation has not been submitted for any degree or examination at any other university.
3. This dissertation does not contain other persons data, graphs or other information, unless specifically acknowledge as being sourced from other person.
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5. This dissertation does not contain text, graphics or tables copied and pasted from the internet, unless specifically acknowledged and the source being detailed in the dissertation and in the reference sections.

Signed:……………………………………………………………………

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CHAPTER 1
GENERAL INTRODUCTION

Broiler breeder production is the one of the most challenging enterprises for animal nutritionists due to the rapid growth rate, high food intake and the risk of obesity that can lead to a decrease the rate of eggs laid and production efficiency. Broiler breeder hens have a rapid growth rate when compared with layers, and achieve the body weight (BW) at maturity soonest. If fed *ad libitum*, these birds would eat more food than do layers. Broiler breeder diets are formulated to meet their daily requirements for energy and protein, while minimising production costs. Daily feed allowance is commonly restricted as a way of controlling growth rate, limiting BW gain and to avoid metabolic problems, mortality due to obesity, multiple ovulations and low fertility. Because of the controlled feeding, nutrition of broiler breeder birds is a more complicated activity to render. Levels of protein and energy play a much important role in the performance of broiler breeder hens. Where there is slight difference in the amount of these nutrients, production can be negatively affected. These birds are always expected to achieve maturity with ideal BW and the ratio of protein: energy has to be satisfactory to promote optimum performance in lay in order to produce the highest possible number of hatchable eggs per hen. Performance is not only affected by nutritional imbalances but also by the strain and age of the chicken. Additional levels of amino acids in the diet could improve broiler breeder efficiency by increasing egg size, with a higher hatchability and liveability. However, oversupplying those birds with amino acids can also decrease productivity due to the energy cost of metabolism; and profitability, due to the higher dietary costs. The current study was conducted to evaluate the effects of different levels of dietary energy, protein, lysine, and the feed allocation on BW, rate of lay, egg quality and egg amino acid composition of broiler breeder hens after peak production.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Rations are formulated following the recommendation of the primary breeder. Primary breeders offer nutritional advice for each phase of breeder cycle. Further, nutritionists need to balance these recommendations with the locally available raw materials, considering their cost, whilst ensuring that the breeder receives a nutrient balance to optimise performance. The recommendations published by the primary breeder are created by different means, but in many cases the scientifically published literature investigating the optimum dietary energy to protein ratio required for breeding hens after production is lacking. Nutrient requirements for breeder females during the rearing and pullet-layer transition have been more extensively researched and therefore are not included in this review.

Dietary energy and protein, and most especially lysine are amongst the most critical nutrients in broiler breeder formulations. The current review will focus mainly on the relevant literature published to date with regards to requirements and performance during the production cycle.

2.2. Growth and development in broiler breeder hens

2.2.1 Growth and development from hatch to lay

Broiler breeder hens have a rapid growth rate from hatch to maturity. The performance of these birds during the laying period is affected by the BW gain and food intake attained during their developing phase (Tolkamp *et al*., 2005). Body weight during the rearing phase is of great importance in improving egg production. Hens with heavier BWs lay heavier eggs, and this in turn results in heavier hatching chicks (Wolanski *et al.*, 2007). During the growing phase, nutrients are required mainly for protein and lipid growth and maintenance (Hruby *et al*, 1994). Broiler breeders can gain weight on very small food allocations, thus *ad libitum* feeding or incorrect management of the feeding program can lead to a higher incident of obesity. Obesity has been reported to adversely affect egg production, therefore broiler operations require a very intensive management program in order to maintain flock uniformity and increase egg production by minimizing excess BW gain (Fattori *et al.*, 1991). Female broiler breeder's reproductive efficiency can be affected by several factors taking place during the process of egg formation until incubation and these include BW (Harms & Ivey, 1992), hen's age (Silversides & Scott, 2001), duration of egg storage (Silversides & Scott, 2001) and environmental stress (Leeson, 1986).

2.2.2 Growth and development in the pre- lay period

This period is of extreme importance for the development of sexual characteristics. Comb growth provides a strong indication of sexual maturation (Joseph *et al.*, 2003) and good flock uniformity allows for improved performance throughout the beginning of production cycle (Bartov & Wax, 1998). Female broiler breeders are housed by age. Body weight management and lightning programmes can allow birds to reach sexual maturity at the same time (Brake *et al.*, 1989). The nutritional management of breeder flocks include different phases, to meet the changing bird's requirements to sustain growth, maintenance and production. Flock uniformity during this stage is essential, as when the flock is not uniform, some birds will be overfed and some underfed negatively influencing the maturation process in some birds (Robinson *et al.*, 1995).

The process of maturation is controlled by hormones produced in the hypothalamus that causes the release of gonadotropins by the anterior pituitary into the blood stream, resulting in the growth of immature follicles into the egg yolk. At this time, the breeders should have a mature follicle every day (Zuidhof *et al.*, 2007). Feed restricted broiler breeders, have higher levels of plasma growth hormone than breeders fed *ad libitum* (Bruggeman *et al.*, 1997) and reach higher levels of peak production than the fully fed birds (Lee *et al.*, 1971)

Environmental factors, namely temperature and relative humidity, might have an effect on the desired food intake. Very high temperatures could negatively affect food intake, resulting in a decline in egg production (Sakomura *et al.*, 2003), while very low temperatures will result in an increase in desired food intake. Although this may not be possible to achieve in feed restricted birds, lower energy intakes in cold temperatures may also result in a decline in egg production (Decuypere *et al.*, 2006). Therefore environmental temperature and relative humidity need to be considered when formulating feeds for broiler breeder hens during this critical period to meet their requirements in this stage.

2.2.3 Growth and development from point of lay to end of the production cycle

Broiler breeder hens have a faster growth rate, a higher desired food intake and achieve a lower peak with poorer persistency of lay, compared with egg-type layers (Robinson *et al.*, 1993). During the early stages of production, the size of eggs are small and breeders have a low rate of production owing to their body size (Vieira & Moran, 1998) and also because the breeders in the beginning of production reach maturity of the organs, but it is only when they are in the peak of production that they reach the physical maturity (Decuypere *et al.,* 2006).

Throughout the breeding cycle egg size increase according to the birds age (Lewis *et al.,* 1998). Silversides & Scott (2001) found similar results with layers. Broiler breeders will reach peak production when the flock is about 31 weeks of age (Spratt & Leeson, 1987) and although peak production is generally lower than that observed in egg- type layers, it can be improved if the right feeding management program is applied from the early phases of production.

After peak production and as the hen age, there is a steady decline in egg production (Renema *et al.*, 2007), which is more pronounced in broiler breeder hens than in layer hens (Figure 2.1). Eggs tend to be heavier due to a heavier mature BW and it is necessary for the feeding program to be controlled in order to prevent negative effects of obesity. However, an increase in egg weight does not necessarily mean that there will be an increase in the fertility of these eggs. Vieira & Moran (1998) investigated the effect of age on the performance of broiler breeder hens between 27 and 62 weeks of age. Hens at 27 weeks of age showed low egg weight, percent of yolk and chick weight compared with those of birds at 62 weeks of age but hatchability was not affected.

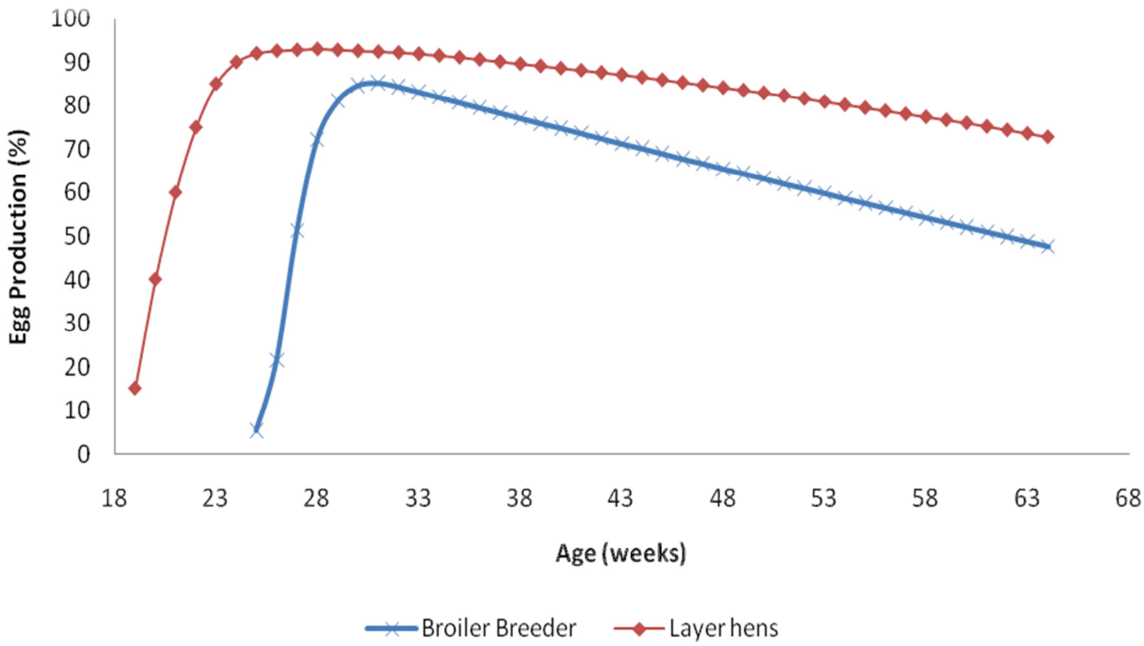

Figure 2.1 *Diagram displaying egg production over age (weeks) in broiler breeder and layer hens.*

2.3 Nutrients requirements of broiler breeder hens

The nutrient requirements for broiler breeder hens are not constant throughout the life of the birds. During the growing period, nutrient requirements change constantly but they start high to support the birds' rapid growth rate (Fisher, 1998). During the first weeks of life, bone development occurs, to establish a good frame on which to grow muscle tissue later. During this stage the sexual organs also develop (Leeson & Summer, 1984). Hence, the provision of nutrients should be sufficient to support the development of all tissues without negatively affecting the development of the birds (Bennett & Leeson, 1990). To describe an ideal feeding program for broiler breeders is difficult, and research has focused on nutrition in the growing and laying phase, where nutrients are required to promote the maximum performance (Lee *et al*., 1971; Fattori *et al*., 1991; Hocking *et al*., 2002). Amino acids, energy and calcium are the most critical nutrients for good production (Fisher, 1998).

The correct balance of protein and energy in the diet plays an important role in the growing phase as much as it does in the laying phase. Nutrient requirements for amino acids during the laying period are additive, therefore the total daily requirement equals the requirement for maintenance added to that for egg production (Fisher, 1998). Breeders that attain the target BW may present a good synchronization between ovulation and oviposition owing to the orderly recruitment of follicles (Renema *et al*., 2007). An imbalanced energy: protein ratio in the diet could result in overfeeding or underfeeding the hens. If the hens are overfed during the rearing period, they would reach the laying period with BWs above the expected target (Lee *et al.,* 1971), which is the result of higher fat deposition in the body, instigating excessive follicular development at the beginning of laying period, those follicles are less responsive to LH (Decuypere *et al.,* 2006), with increased incidents of ovarian abnormalities (Hocking, 2004; Chen *et al.,* 2006) compromising egg production, principally in the peak of production (Robinson *et al*., 1995). Fertility in obese birds is also negatively affected owing to the fat deposition in the abdominal cavity, which interferes with the normal migration of sperm to the place of fertilisation in the reproductive tract (Walsh & Brake, 1997). If the birds are underfed during the rearing period, sexual maturity is delayed (Enting *et al.,* 2007); since sexual maturity is dependent of BW and body composition (Ciacciariello & Gous, 2005). Fattori *et al.* (1991) established that for every 13.7 g of BW below recommended levels, there was a one day delayed in flock maturity. Broiler breeder reach maturity as soon as hypothalamic maturity occurs (Sunder *et al*., 2008), with an interaction between growth factors and gonadotropins (Decuypere *et al.,* 2006) being stimulated by feeding (Sunder *et al.,* 2008). If the low nutrient supply continues into the laying period, the body fat reserves might be depleted in an attempt to support egg production (Sun & Coon, 2005). As a consequence, birds lose weight and egg production would be below expectation through the cycle (Scanes *et al.*, 1987) with more frequent double- yolked eggs and fewer of days in production (Fattori *et al.,* 1991).

Broiler breeder hens start to lay eggs around 24 weeks of age. At the beginning of the production cycle, small egg size and low fertility are often observed and are believed to result from the incomplete development of the oviduct and ovarian follicles (Robinson *et al.*, 2001). During this stage, nutrient requirements for maintenance and production need to be adequately supplied. In some broiler breeder operations, dietary nutrient content remains constant over the laying period. However, nutrient content in the diet will increase with an increase in production, until peak production, after which it is decreased with a decrease in production (Spratt & Leeson, 1987). When breeders reach maximum egg production, with the flock ranging around 80% to 85% rate of lay, the birds' requirements increase owing to an increase in egg output (Scanes *et al.*, 1987). At the age of around 39 to 40 weeks, breeders start showing a decline in the egg production and the nutrient requirements also decrease accordingly, thus necessitating adjustments on the feeding schedule used to feed the birds (Fisher, 1998). These adjustments are required with a decrease in energy: protein ratio in order to control BW, since hens consume more nutrients than they process into eggs, after peak (Joseph *et al.,* 2000) and high energy diet will increase BW and proportional content of fat (Bennett & Leeson, 1990) or deficiency of amino acids can limited amount of protein formed into the egg (Butts & Cunningham, 1972) and by so doing, egg production and fertility of settable eggs will be affected (Renema *et al.*, 2007).

2.3.1 Energy requirements

The role of energy in broiler breeder's metabolic functions is to provide energy needed for growth, maintenance and egg production. These requirements are variable and depend on a number of factors such as BW (Spratt & Leeson, 1987), environmental conditions (Vieira *et al.*, 2007), age (Gardner & Young, 1972), growth rate (Rabello *et al.*, 2006), and rate of egg production (Spratt &

Leeson, 1987). Environmental conditions affect the level at which energy needs to be included in the diet. When the birds are exposed to temperatures within the thermo neutral range, these requirements do not vary much. On the other hand, unsuitable ranges in temperature can affect the energy requirements (Sakomura *et al.,* 2003). Rabello *et al.* (2006) have shown that maintenance requirements for energy decrease with an increase in temperature from 28°C. However Sakomura (2003) concluded that temperature limits are not the same for all birds, because of the change in BW, feed intake and activity. Energy intake is accounted for by partitioning it into maintenance, fat-free tissue growth, fat synthesis and the cost of catabolising amino acids not utilised for protein synthesis (Sklan & Plavnik, 2002). During the growing phase, energy needed is mostly for the development of body mass (protein and lipid) and the sexual organs (Robinson *et al*., 2007). If BW increases, requirements will also increase until the birds reach maturity, after which the energy required will mostly be essential for maintenance and egg production, and tissue deposition will occur only if energy has met the maintenance requirements (Sakomura, 2003). As the energy requirement for maintenance is dependent on BW, large birds would have a higher energy requirement for maintenance than smaller birds (Robinson *et al*., 1995).

2.3.2 Energy requirements in the pullet-layer transition

The pullet-layer transition is the most critical phase in the female broiler breeder's life (Robinson *et al*., 1995). During this phase, the complete development of the bird's reproductive organs occurs, and the energy consumed is partitioned between completing skeletal growth and muscle deposition, as well as to building fat reserves and developing reproductive organs for egg production (Joseph *et al*., 2002). In this phase the flock has to gain enough weight to sustain further egg production. However it should not be overfed to avoid the negative effects observed in overweight flocks. Body weight (Robinson *et al*., 1995; Rabello *et al*., 2006), body composition (Scanes *et al*., 1987) and flock uniformity (Joseph *et al*., 2000) are the major limiting factors because if the flock does not gain weight through the transition period, the birds will exhibit lower egg production and hatchability at the beginning of the laying phase (Ciacciariello & Gous, 2005). If broiler breeder hens reach the pullet-layer transition with BWs below the expected target owing to low nutrient intake, sexual maturity can be significantly delayed (Robinson *et al*., 1995). Sunder *et al*. (2008) also reported that in order to maintain high percentage levels of fertility and hatchability at the end of production, controlled energy feed during the laying period is advised. Robinson *et al*. (1995) report that requirement for optimum egg production is around 239 Kcal/day (999.98 KJ/day). Sunder *et al.* (2008) reported that breeders consuming an average of 349 Kcal/day (1461.26 KJ/day) maintained high egg production and better feed conversion efficiency.

2.3.3 Energy requirements during the laying period

During the laying phase deposition of fat and energy increase while protein deposition decrease (Chwalibog, 1992) The utilisation of energy when fed above maintenance requirements will be partitioned into protein and lipid synthesis (Sakomura, 2003); and needs to be enough to sustain egg production, which consists of the energy contained in the egg and the energy utilised for egg production (Rabello *et al*., 2006). Energy is required for the synthesis of fatty acids and protein, transport of precursors to the egg, egg production and maintenance of reproductive organs (Scanes *et al*., 1987). Equations to calculate energy requirements for broiler breeders take into account BW, daily egg mass and environmental conditions to predict the energy requirements (NRC, 1994).

At the onset of lay, broiler breeder hens exhibit a low production rate and produce small eggs. Energy intake at this stage is essential because they are not completely mature. Energy intake will be partitioned between tissue accretion and the start of egg production (Spratt & Leeson, 1987) and, if feeding above requirements, will be deposited as fat (Rabello *et al*., 2006). When breeders reach peak production, more energy is required to ensure the production of high quality eggs (Scanes *et* *al*., 1987) however excessive fat deposition due to high energy feed intake, will decrease percentage of production at peak or even delay peak of production.

Sunder *et al.* (2008) suggested that ideal energy restriction is essential to maximise performance in breeders during the late lay phase of production. As broiler breeders age, they continue to increase in BW (Leeson & Summers, 1984), and produce heavier eggs (Gardner & Young, 1972), however egg production declines. Broiler breeder hens receive increasing levels of energy in the diet during the early laying period because heavier birds will produce heavier eggs (Harms & Ivey, 1992) with higher availability of nutrients into the egg (Lourens *et al.,* 2006) and consequently, a higher weight of yolk and albumen (Spratt & Leeson, 1987). Contrarily, Gardner & Young (1972) reported that an energy increase in broiler breeder diets leads to increased egg weight with large yolk and less albumen, and a relative decrease in shell weight decrease with reduced egg breaking strength. Lesson & Summers (1984) showed that the ideal energy intake for maintenance and egg production was 370 Kcal/bird/day (1548 KJ/bird/day). However, Spratt & Leeson (1987) reported that the energy requirement during peak production was 385 Kcal ME/bird/day (1610.8 KJ ME/bird/day), which agrees with subsequent work where Spratt *et al*. (1990) reported that 325 ME Kcal/day (1359.8 KJ ME/day) for broiler breeders is not sufficient for optimum performance since hens tend to produce smaller eggs. More recent work (Sunder *et al*., 2008) showed that 349 Kcal/day (1461.26 KJ ME/day) fed from 21 to 64 days old, delayed sexual maturity, but nonetheless maintained higher feed conversion efficiency and overall egg production. It is calculated, through mathematical modelling, that the energy requirements are 10.04 KJ/g of egg and 31.9 KJ/g of weight gain (Rabello *et al*., 2006). Therefore, energy requirements will differ as breeders get older. An example is reported by Attia *et al*. (1995) where increased energy allotment levels for broiler breeders will affect negatively egg production at 45 weeks of age. Older hens have high fat tissue deposition and low metabolic activity which may reduce requirements for ME per kg of BW (Rabello *et al.,* 2006).

2.3.4 Protein and amino acid requirements

Protein and amino acids are essential for the development and reproductive performance of broiler breeder hens and their requirements change substantially as there is an increase in body size when the bird approaches maturity and peak egg production (de Beer & Coon, 2006). Once peak production has passed, there is a decline in protein requirements owing to the decline in egg production. Dietary protein must supply all the essential amino acids in order to meet the requirements for growth (Robinson *et al*., 1995), maintenance (Fisher, 1998) and production (Harms & Ivey, 1992). It is complex to predict amino acid requirements for growing birds, as they keep changing with the physiological status of the bird. An imbalance in the dietary energy to protein ratio can increase or decrease the metabolic rate and change the body composition of breeder hens (Macleod, 1997); however, once the birds reach maturity and stop growing, the only amino acid requirements are for egg production and maintenance; the changes in these requirements is due to egg weight and egg production.

Protein is the most costly nutrient in the diet; hence its quantity and quality are very important in determining the level of performance achieved by the birds as the appropriate selection of protein sources would also cost an impact in determining the costs of production. Butts & Cunningham (1972) suggested that efficient use of protein is the most important economic factor in reducing high production costs and balanced rations containing minimal protein levels are highly recommended for this purpose. Performance levels can easily be influenced by the choice of the feeding programme (Lopez & Leeson, 1994; Fisher, 1998; Rabello *et al*., 2006). Additionally, factors such as BW, feed consumption, and energy concentration in the diet, egg production and hatchability play an important role in the choice of dietary protein concentration (Lopez & Leeson, 1994). Protein and amino acids are believed to have a minimum effect on egg size when compared to energy levels in the breeder diet (Spratt & Leeson, 1987), however egg size may also be affected by the dietary protein content and inclusion of essential amino acids (Lopez & Lesson, 1994). When subjected to a dietary protein deficiency or fed an amino acid-imbalanced diet, the bird prioritises body maintenance (Gardner & Young, 1972) and egg production, at the expense of egg weight (Lopez & Leeson, 1994).

2.3.5 Protein requirements during the pullet-layer transition

Throughout the rearing period, BW is controlled through feeding regimes based on restricted energy and protein intake, avoiding large increments in BW. However, a fine balance is to be maintained to allow for the development of sexual organs which will support production at later stage. Heavier birds reach sexual maturity earlier than lean birds (Benett & Leeson, 1990), but that does not necessarily mean that heavy birds will outperform the production of leaner broiler breeder hens. Low levels of dietary protein during this phase results in an imbalance in the energy to protein ratio (Gous & Nonis, 2010) and as a result, if the birds were fed *ad libitum,* they would consume an excess of energy in order to compensate for the insufficient amounts of protein in the diet (Spratt & Leeson, 1987). Excessive energy consumption causes an excessive increase in BW thus resulting in an increased number of defective eggs such as double- yolked eggs (Sakomura, 2003), poor shell quality (Wolanski *et al.,*2007), and a decrease in fertility and hatchability (Lopez & Leeson, 1995a) due to the development of multiple ovarian follicles into the hierarchy (Fisher, 1998).

Feed allocation at 20 weeks of age was cited in a number of published works including that by Robinson *et al*. (1995) which emphasised that overfeeding up to 20 weeks of age will result in poor flock uniformity, since protein levels will influence skeletal size at early age and can result in reduced reproductive fitness of these birds (Leeson & Summers, 1984). Poor uniformity in broiler breeder hens is not desirable, because will delay onset of lay, with lower cumulative egg production

(Hudson *et al.,*2001) and light females will lay smaller eggs (Enting *et al*., 2007). Broiler breeder hens have an ability to produce multiple first follicles in the ovary when overfed (Yu *et al*., 1992), increasing the number of double- yolked eggs during production (Robinson *et al*., 1993). Conversely, low nutrient intake could result in poorer reproductive efficiency. Walsh & Brake (1997) showed that feeding pullets a diet with 11% CP at 18 weeks of age resulted in lower fertility rates and higher mortality, when the females were 37 weeks old. Birds consuming less than 18% CP in the diet at 20 weeks of age also exhibited reduced fertility. This is in agreement with Joseph *et al.* (2002), where feeding 18% CP in the diet resulted in significantly fewer double-yolked eggs compared to feeding 16% CP in the diet for broiler breeders.

Egg weight in broiler breeder hens will differ in size depending on the female BW (Robinson *et al*., 2007) and age (Silversides & Scott, 2001). At the onset of lay, breeder hens will lay eggs small in size, which are not desirable as they are not suitable for incubation (Hocking *et al.,* 2002), as egg size has a direct relationship with day-old chick hatching weight (Wolanski *et al.,* 2007). Vieira & Moran (1998) reported that chicks hatched from young broiler breeder flocks exhibit increased mortality rates and lower performance. Abiola *et al.* (2008) showed that chicks from smaller eggs had a reduced BW compared with chicks from heavier eggs. Good practices of feed restriction for broiler breeders at early age will ensure the correct protein intake in the diet and diminish the effects of lower performance in broiler breeder hens during production period.

2.3.6 Protein requirements in the laying period

The dietary protein and amino acid content are the most important nutrients in obtaining a uniform flock (Joseph *et al*., 2000), optimum levels of egg production (Fisher, 1998), egg weight (Gardner & Young, 1972; Harms & Ivey, 1992), egg quality (Butts & Cunningham, 1972), and high fertility and hatchability (Vieira *et al.,* 2007). Lack of uniformity will result in eggs of different sizes, and some birds starting production, earlier than others. At the onset of lay, hens often lay small eggs and the size of these eggs increases as the hen's age increases. Once the hens reach peak of production, requirements for protein present a small increase owing to the increase in rate of lay. Spratt & Leeson (1987) reported that 19 g protein intake bird/day was sufficient to maintain normal reproductive performance through peak egg production. Joseph *et al*. (2000) reported an increase in the rate of egg production as the amount of dietary protein increased from 14, 4 g bird/day to 22 g bird/day in broiler breeders from 24 to 56 weeks of age. Consequently low levels of protein intake reduce egg production. Butts & Cunningham (1972) indicated that protein levels below 12% protein in the feed decreased egg production and egg size. Egg production can be decreased greatly when protein requirements are not met; Joseph *et al.* (2000) showed that values below 14% of dietary protein in broiler breeders' diet at 25 weeks of age decreased egg production from 65.2% to 49.8%, compared with birds receiving 18% of protein in the diet. Harms & Ivey (1992) also found similar values for egg production, egg weight and egg mass which were achieved with daily protein intakes greater than 18.55 g per bird/day.

Yolk and albumen also change with different levels of protein content in the diet. Albumen and whole egg protein concentration increased as dietary protein levels increased (Butts & Cunningham, 1972). Gardner & Young (1972) concluded that increases in the levels of protein in the diet from 12% to 18% resulted in an increase weight of all egg contents, but particularly the yolk. However, an increase in yolk weight might not only be a function of dietary protein but also of the age of the hen. Older hens exhibit heavier BWs and consequently produce heavier eggs with a greater proportion of yolk and a lower proportion of shell and albumen (Gardner & Young, 1972; Harms & Hussein, 1993; Vieira & Moran, 1998).

2.4 Feed restriction vs. *ad libitum* feeding

Increased food consumption has been shown to result in poor performance of broiler breeder hens in terms of reproductive performance, this being due to the excessive BW of such birds when they reach sexual maturity and start laying eggs (Robinson *et al.,* 1995; Yaissle & Lilburn, 1998). Currently, feed restriction is applied from as early as 4 days of age and maintained thought out the rearing and production cycles. When broiler breeders are offered a balanced diet *ad libitum*, it ensures that birds receive an adequate amount of protein to satisfy their production and maintenance needs (Harms & Ivey, 1992: Joseph *et al*., 2000). De Beer & Coon, 2006 showed that hens receiving a diet with low protein intake will take longer to reach sexual maturity than hens with adequate protein intake in the diet. However, when birds are fed *ad libitum*, they over consume energy, and the excess is deposited predominantly as body fat, which has a negative effect on carcass composition decreasing the performance of the broiler breeder hens (Lopez & Leeson, 1994; Rabello *et al.,* 2006). Numerous studies have been conducted in an attempt to improve reproductive performance and egg production of broiler hens and the most accepted solution in such cases has been the implementation of feed restriction. Obesity results from overfeeding which is often seen with *ad libitum* feeding programmes (Mench, 2002) and is a major factor limiting broiler breeder production. Sexual maturity is the phase where broiler breeder hens are much more sensitive to the amounts of food consumed and thus further affecting production and performance of such birds (Robinson *et al*., 1995). Therefore, restricted feeding is a technique utilised to control BW of broiler birds to achieve optimum production. This technique is adapted in the breeder life from rearing, with a small increase in food allocation until breeders reach sexual maturity. When feed intake is restricted in broiler breeder hens, BW is controlled through reduced energy intake. Joseph *et al*. (2002) reported that feed restriction programmes require more time than necessary for the birds to attain suitable BW at sexual maturity and will improve performance until the end of production life of breeders (Fattori *et al*., 1991), with a better conversion rate per dozen eggs (Lee & Morris, 1971). Nevertheless, birds fed *ad libitum* exhibit poor fertility and relatively higher rates of late embryonic deaths (Hocking *et al*., 2002). Therefore, feed restriction is an important practice to reduce cost of production (egg/hen) and obtain optimum performance in broiler breeder hens.

Robinson *et al*. (1995) reported in an experiment with broiler breeders separated according to their BW groups, that the heaviest bird (105%) had the best performance in egg and chick production and this maybe because the heaviest flock produce larger eggs thus heavy chicks. Hocking *et al*. (2002) stated that restricted birds have a higher total number of settable eggs, fewer defective eggs and higher fertility and hatchability than those feed *ad libitum*. However the technique of feed restriction was also reported to decrease productivity with a decrease in BW resulting in a delay of 7 days for the pullet, compared with hens on the high BW profile (Renema *et al.,* 2007). Fattori *et al.* (1991) also reported a delay in the onset of lay with severe feed restriction in broiler breeder hens. Furthermore, optimal levels of nutrient content for broiler breeders must be investigated so as not to compromise the performance of the hens.

2.5 Conclusions

Optimal levels of food intake, energy and protein in the diet can positively affect the development of growing birds and flock uniformity from the rearing period and consequently improve the performance of the breeders through their laying cycle, with an increase in egg production, egg weight in the first laid and 1 day old chick weight. Thus, management of food intake and therefore BW is fundamental for reproductive efficiency. Restricted feeding program is essential for good performance of the broiler breeders, where the minimum excess in feed intake can cause obesity and decrease production.

With constant changes in broiler breeder genotypes to meet the growing demands for poultry meat, it is likely that these requirements and daily allowances change. In addition, most research conducted in broiler breeder nutrition has focused on dietary crude protein levels or crude protein intake. Modern poultry nutrition has moved past this parameter, concentrating on amino acid requirements and dietary supply rather than crude protein. Very little research has investigated the effects of specific dietary amino acid concentration on broiler breeder performance. This chapter highlights the gaps in the literature and had led to the experimental work conducted for this thesis.

CHAPTER 3
EFFECTS OF LYSINE AND PROTEIN INTAKE ON BROILER BREEDER PRODUCTION AND EGG QUALITY

3.1 Introduction

The nutritional management of broiler breeder hens for egg production is more challenging than it is for egg-type layers. Birds, in general, have the capacity to adjust feed intake as is needed to meet their requirements for growth and production, but because of genetic selection for growth, broiler breeders tend to over-consume feed (Fattori *et al.*, 1991; Lopez & Leeson, 1994), and become obese resulting in a decrease in reproductive performance (Hocking *et al.*, 2002). However, feed restriction techniques have been widely utilised to minimise this problems.

For many years, protein and amino acid requirements for broiler breeder birds have been thought to be similar to that of egg-type hens and this has also contributed to the decrease in production because the metabolism of these birds is different (Ohta *et al.*, 2004). Lysine is often, the first limiting amino acid in broiler breeder diets where low levels can result in low performance through the breeder's production cycle. However little is known about how those birds utilise the lysine consumed into egg production and maintenance. Research has shown that a deficiency of lysine and protein intake during the production period affects egg weight (Butts & Cunningham, 1972), however, not many researchers could elucidate the partitioning of nutrients for maintenance and egg formation, and how this can affect egg production, and later embryo growth and chick performance. Harms & Ivey (1992) reported that broiler breeders require a daily intake of 814 mg of lysine for a daily production of 45.74 g of egg content. Nevertheless, few experiments have been performed on the effects of lysine intake in egg amino acid composition, and its effects on embryo growth.

Bird's egg content is composed of two major proteins; Ovovitellin, which is found mainly in the yolk and contains a high level of arginine, leucine, lysine and glutamic acid (Romanoff & Romanoff, 1949); and ovalbumin, which is largely found in the albumen and is composed of leucine, alanine, aspartic and glutamic acid (Romanoff & Romanoff, 1949). Sunny & Bequette (2009) showed that embryos from small eggs had less gluconeogenic amino acids in the blood than did embryos from heavier eggs. Ohta *et al.* (2004) suggested that administration of amino acids to chicken embryos can improve chick weight for meat-type, but not for layer chicks, and supports the idea that amino acid content in broiler breeder eggs may be sufficient for hatching but not for the embryo to grow to its full genetic capacity. Most experiments pertaining to amino acid egg composition were conducted with the administration of amino acids *in ovo*, although how the broiler breeders will partition nutrients for amino acid composition in the egg if different levels of lysine are presented in the feed is not clearly known. A better understanding of the nutrient partitioning in breeder hens could provide a basis to manipulate the diet and improve the amino acid provision to the embryo. Therefore, the objective of the current experiment is to investigate the effects of different levels of protein and amino acid intake on broiler breeder performance, BW and amino acid composition in the egg when managed under a controlled feeding programme.

3.2 Material and Methods

3.2.1 Housing and management

Nine- hundred broiler breeder females and 90 males Cobb 500 were used in the study. The birds were kept to 20 weeks of age in a commercial rearing farm under a lighting programme of 9L: 15D. Thereafter the birds were transferred to Ukulinga Research Farm, University of KwaZulu-Natal - Pietermaritzburg, South Africa. The twenty week-old broiler breeders were placed in an open-sided house, divided into eighteen floor pens each with a dimension of 3 x 3.5 m covered with wood shavings. Each pen included two line feeders with exclusion grids, male feeders, bell drinkers and nesting boxes with wood shavings. Artificial light was provided to supply 12L: 12D with supplemental lights switched on from 6:00 to 7:00 AM and between 4:00 to 6:00 PM. Fifty hens and 5 males were placed in each pen, giving a stocking density of 5 birds/ m^2.

3.2.2 Diets and experimental treatments

Birds in rear were fed a basal feed recommended for growing broiler breeders (Cobb–Vantress, 2008). At 20 weeks old, the birds were fed 100g of a basal feed/bird/day and each week the feed allocation was increased by 10 g. At 26 weeks hens received 160g feed/bird/day and the experimental feed was commenced. The feed allocation remained 160g/bird/day until 60 weeks and the breeders were fed six different diets from 26 to 60 weeks of age with the experimental feeds allocated in a randomized block design. Six treatments were used, with 3 replications during the period of 26 to 60 weeks of age. The experimental feeds were produced by blending two basal feeds, a high protein (HP) and a low protein (LP) diet (Table 3.1). The amino acid levels used were modified to provide a balanced mixture between the basal feeds. The feed was designed to provide an intake of 1900 KJ ME / bird day and each treatment had a different mixture of the two basal feeds to provide the desired levels of lysine to be tested (Table 3.2).

Table 3.1 Ingredients of the high protein (HP) and low protein (LP) basal diets.

Ingredients		**Diet**	
	Units	**HP**	**LP**
Maize	%	60.0	71.0
Wheat bran	%	9.60	9.60
Soyabean full fat	%	26.1	15.0
L-lysine HCL	%	0.07	-
DL-methionine	%	0.114	0.03
L- threonine	%	-	0.57
vit+min premix	%	0.26	0.26
Limestone	%	7.20	7.26
Salt	%	0.18	0.29
Monocalcium phosphate	%	0.51	0.53
Sodium bicarbonate	%	0.51	0.20
Potassium carbonate	%	0.54	0.41

Table 3.2 Nutrients analysed in the high protein (HP) and low protein (LP) basal diets.

Nutrients		HP Total	HP Avail	LP Total	LP Avail
AMEn_adult	MJ/kg	11.9	-	11.9	-
EE	MJ/kg	10.8	-	10.9	-
CP	%	15.3		12.8	
Lysine	%	0.85	0.75	0.57	0.50
Methionine	%	0.36	0.33	0.24	0.22
Methionine+cystine	%	0.66	0.56	0.51	0.43
Threonine	%	0.59	0.50	1.00	0.93
Tryptophan	%	0.17	0.14	0.13	0.11
Arginine	%	1.01	0.91	0.76	0.69
Isoleucine	%	0.66	0.57	0.50	0.43
Leucine	%	1.44	1.31	1.26	1.16
Histidine	%	0.44	0.39	0.36	0.32
Phenylalanine+tyrosine	%	1.26	1.10	1.00	0.88
Valine	%	0.78	0.67	0.63	0.55
Ash	%	10.1	-	9.62	-
Crude fibre	%	3.65	-	3.29	-
Crude fat	%	7.13	6.12	5.58	4.85
Calcium	%	2.50	-	2.50	-
Avail. Phosphorous	%	0.25	-	0.25	-
Sodium	%	0.22	-	0.18	-
Chloride	%	0.16	-	0.22	-
Potassium	%	1.00	-	0.80	-
Linoleic acid	%	3.81	-	3.02	-

For statistical purposes, the present trial was divided into two experiments. In the first experimental design birds were divided into four feed groups, with three replications per treatment. Each feed treatment had fixed levels of dietary protein, used throughout the experimental period, which provided each bird treatment with 1200, 1070, 930 or 800 mg lysine/ bird.day, respectively. Basal feeds were blended as follows: 100% HP, 67% HP and 33% LP, 33% HP and 67% LP and 100% LP respectively to obtain treatments offering a lysine intake of 1200, 1070, 930 or 800 mg lysine/ bird.day. In experiment two birds were divided in four feed groups, where on treatment one and two, birds had fixed levels of lysine intake, namely 800 and 1200 mg lysine/ bird.day, respectively; whilst for treatments three and four the lysine composition in the diet was changed every second week (Table 3.3) to provide different levels of lysine in the diet throughout the experimental period. In the third treatment lysine intake was reduced from 1200 mg/d at 26 weeks to 800 mg/d at 60 weeks, while in the fourth treatment; lysine intake was started with 800 mg/d and increased to 1200 mg at 60 weeks.

Table 3.3 Calculated lysine intake for T3 and T4 through the experimental period in experiment 2

Age (weeks)	Lysine Intake (mg/bird/day)	
	T3	T4
26	1200	800
28	1175	825
30	1150	850
32	1125	875
34	1100	900
36	1075	925
38	1050	950
40	1025	975
42	1000	1000
44	975	1025
46	950	1050
48	925	1075
50	900	1100
52	875	1125
54	850	1150
56	825	1175
58	800	1200
60	800	1200

3.2.3 Data recording

All birds were group-weighed per pen at 26 weeks when the trial began. Thereafter, 20 birds per pen were group weighed once every four weeks. Mortality was recorded daily. Eggs were collected three times a day and classified into dirty, clean, and damaged eggs. The collected eggs were then kept in a refrigerated room and weighed three times a week. Egg output was calculated as the mean egg production multiplied by the mean egg weight/100. At 37, 45, 53 and 60 weeks of age, seven eggs were collected from each pen (21 eggs per treatment) for the analysis of egg composition. The eggs were weighed, broken and the yolk separated from the albumen. Then, albumen and yolk were weighed individually and dried, after which the eggshell was washed to remove remaining albumen and dried 24 four hours prior to weighing. The dry shell was used to measure the shell thickness with the use of micrometer (Mitutoyo micrometer, 0-25mm).

Twelve eggs per treatment were selected for crude protein and gross energy analyses; giving a total of 72 samples of yolk and 72 samples of albumen. Yolk and albumen were kept in a refrigerated room, and later frezze-dried. Crude protein was analysed with a LECO FP2000 Nitrogen Analyser and the dumas combustion method (Horwitz & Latimer, 2005). Gross energy was determined with the DDS isothermal CP500 bomb calorimeter (Horwitz & Latimer, 2005).

One egg per pen from the first (37 weeks of age) and last (60 weeks of age) collection were sampled for amino acid composition analyses. To analyse the amino acid composition the samples were first hydrolysed to release the constituent amino acids and thereafter a Beckman Amino Acid Analyser System 6300 was used (Moore & Stein, 1948).

3.2.4 Statistical analyses

The experiment had a completely randomised design. In experiment 1 simple regression analyses using hen age as a group were used to evaluate the effects of lysine intakes on BW, egg production, egg weight, weight gain, egg parameters such as yolk, albumen, shell weight, gross energy, protein and the amino acid composition of yolk and albumen. Significance was set at a 5 % level ($P<0.05$).

In experiment 2, one-way analyses of variance (ANOVA) using Genstat 12th Edition (VSN International, 2009) was used to determine whether there were any differences in BW, egg weight, albumen and yolk weight, eggshell thickness, and egg production throughout the course of the experiment with lysine intake. Least significant differences (LSDs) were used to determine differences ($P<0.05$) between treatment means.

3.3 Results

3.3.1 Experiment 1

Body weight was grouped according to treatments and age. Body weight increased with broiler breeder age as was expected. Regression showed that BW at 37 and 45 weeks at age increased significantly with increase of lysine intake (Figure 3.1), where $y = 0.0004x+3.655$ ($R^2 = 0.393$) and

0.0004x + 3.870 (R^2 = 0.339) respectively. However, from 45 weeks of age to the end of experimental period, BW was not affected by dietary lysine. At 60 weeks old, BW was 4.59; 4.40; 4.60 and 4.42 kg respectively for birds with levels of lysine intake in the diet of 1200, 1070, 930 and 800 mg / bird.day.

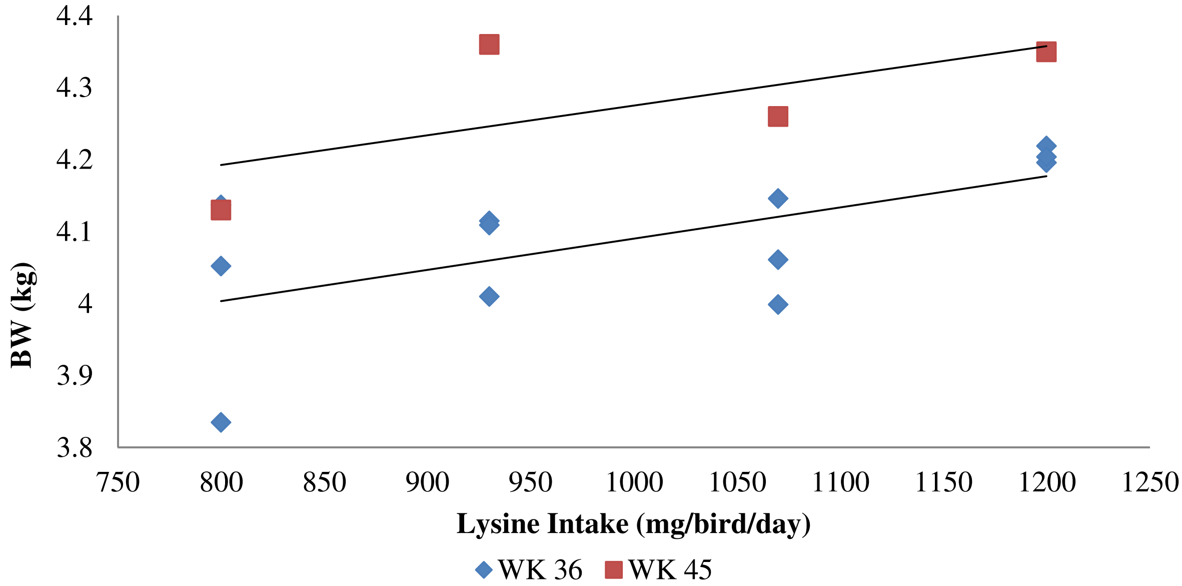

Figure 3.1 Effects of lysine intakes levels in broiler breeder body weight at 37 and 45 weeks old.

Weight gain (WG) was significantly affected by lysine intake at 37 weeks of age, being 12.2, 10.2, 10.9 and 9.8 g per bird.day, respectively for treatments on 1200, 1070, 930 and 800 mg lysine/bird.day, and the linear regression equation was y= 0.005x + 5.669 (R^2=0.336; Figure 3.2). Broiler breeders that had higher lysine intakes had higher weight gains. As the birds aged, the weight gain decreased and no significant response to lysine intake was observed was found at the subsequent weeks until broiler breeders were at 60 weeks old, where the WG was 5.7, 5.0, 5.9 and 5.0 g per bird/day, for birds fed 1200, 1070, 930 and 800 mg of lysine/ bird.day respectively.

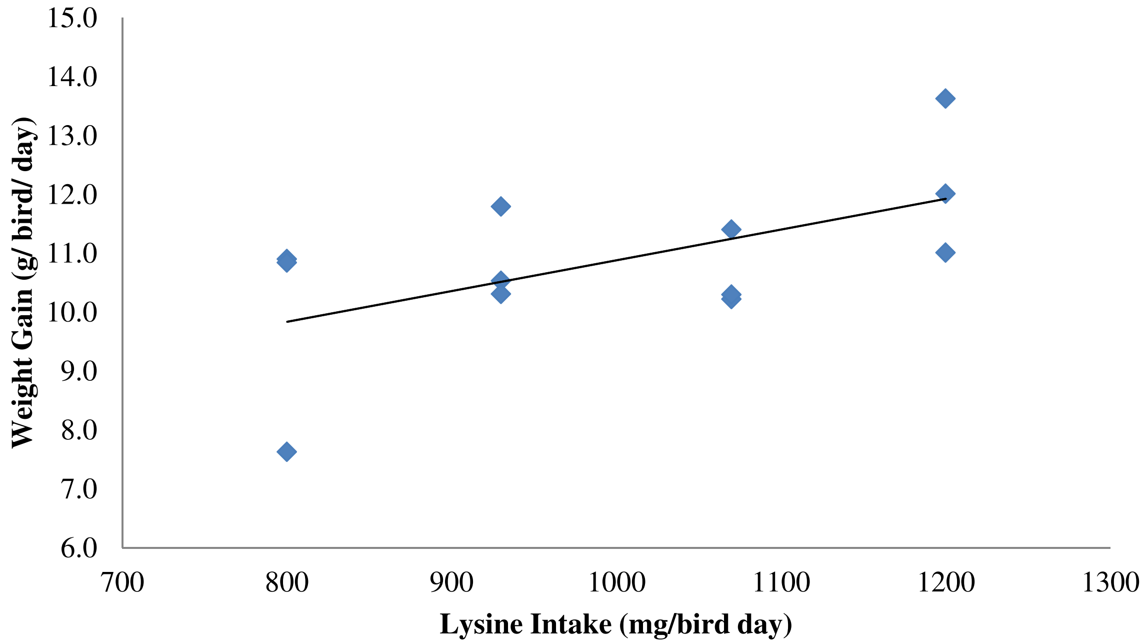

Figure 3.2 Effects of increased levels of lysine in the diet and the relationship with weight gain of broiler breeders at 37 weeks old.

Egg production followed a normal pattern in all treatments (Figure 3.3). Broiler breeder hens started to produce eggs at 26 weeks old; all treatments reached 50% of egg production at 29 weeks old. No significant differences were found in egg production and egg output at any stage of the trial.

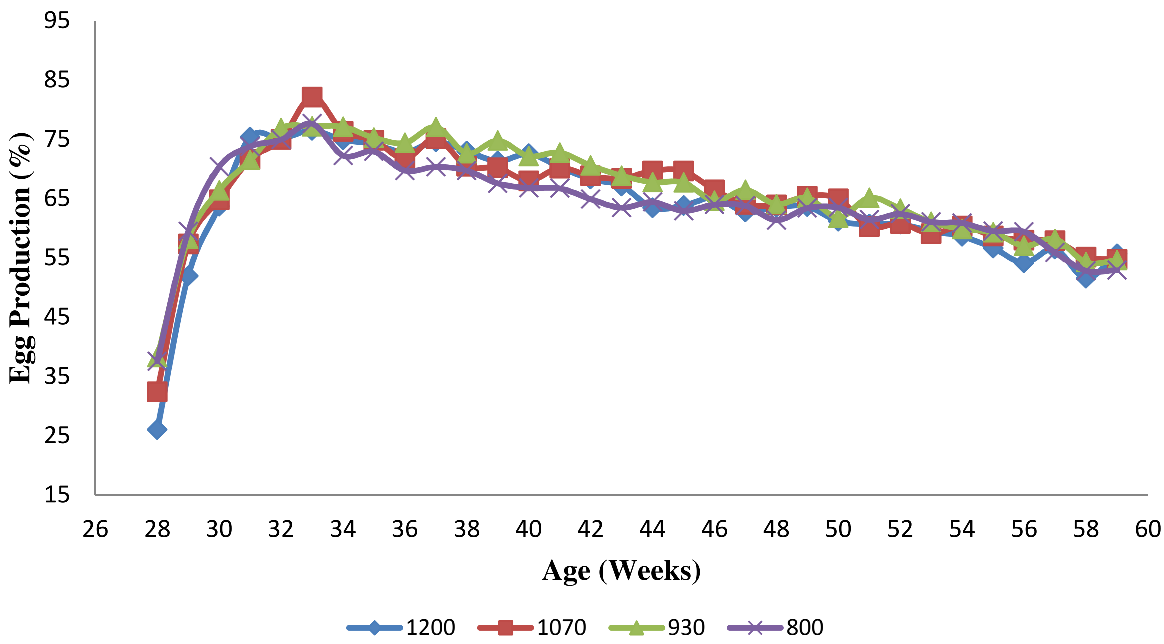

Figure 3.3 Egg production curve of each experimental treatment from 28 to 60 weeks of age.

Increased lysine intakes had a significant effect ($P<0.05$) on egg weight as shown in Figure 3.4. The regression equation for egg weight was y = 0.004x +63.79 (R^2 = 0.521). These differences were significant from 37 weeks old up to 53 weeks of age. Additional levels of lysine in the feed increased egg weight up to 2 g. Egg yolk, albumen and egg shell weight were not affected by dietary lysine intake. However the yolk: albumen ratio responded positively as the broiler breeder aged ($P<0.05$).

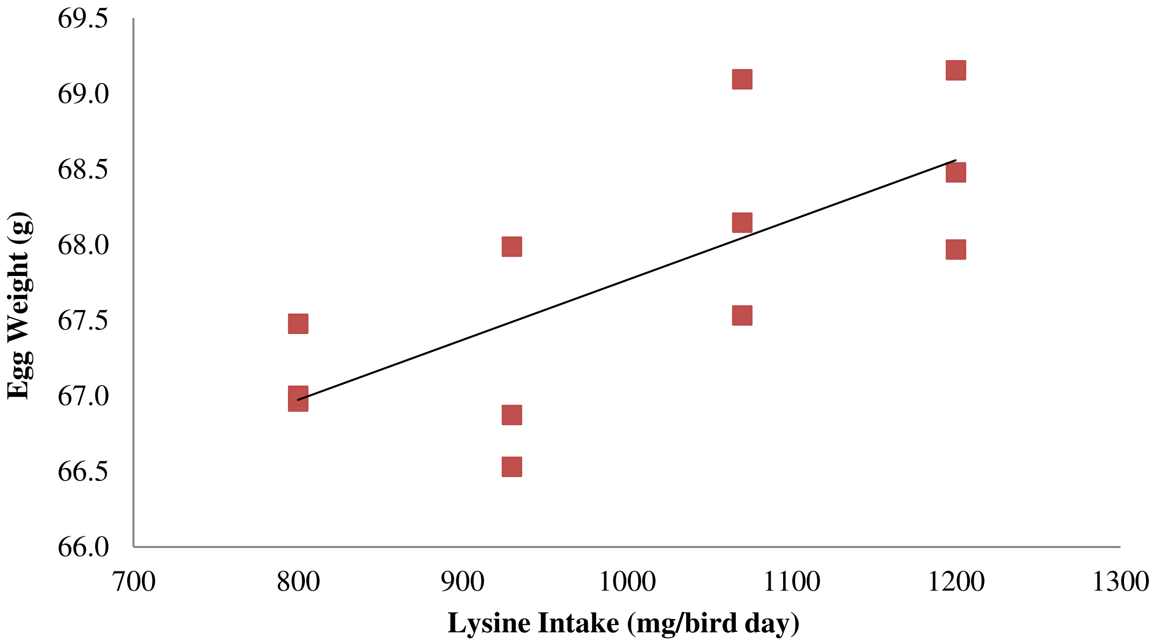

Figure 3.4 The response in egg weight to lysine intake of broiler breeders at 53 weeks of age.

A strong correlation between the percentage of albumen and yolk to egg weight ($P< 0.005$) was found in this trial. Yolk percentage increased with an increase in egg weight (Figure 3.5) y= 0.462x – 0.5767 (R^2= 0.85) and albumen percentage in the egg will decrease with an increase in egg weight (Figure 3.6) y= 0.236x + 70.541 (R^2= 0.47).

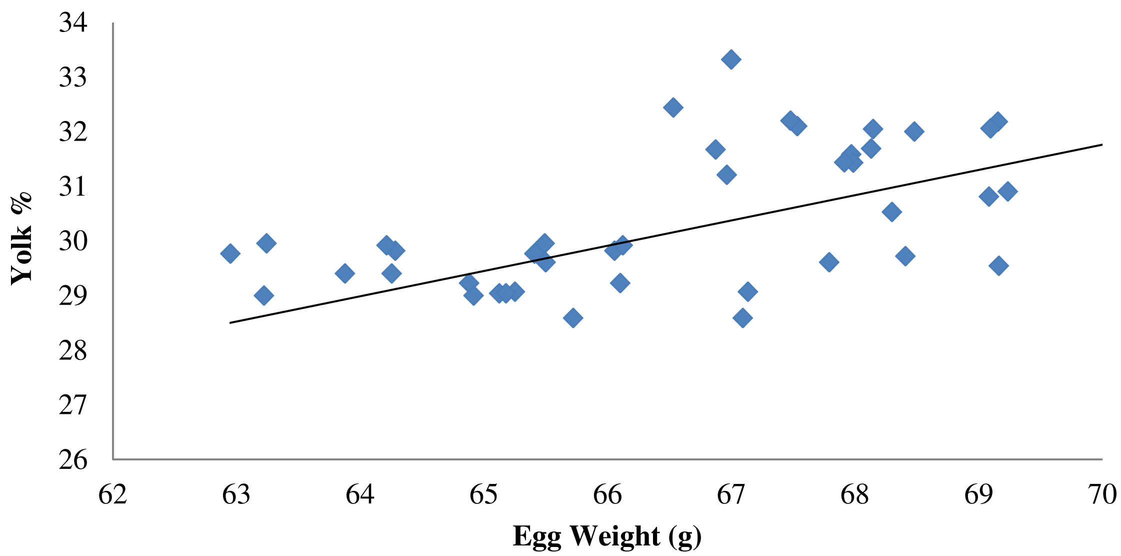

Figure 3.5 Relationship with yolk percentages and egg weight in broiler breeder egg from 37 to 60 weeks old.

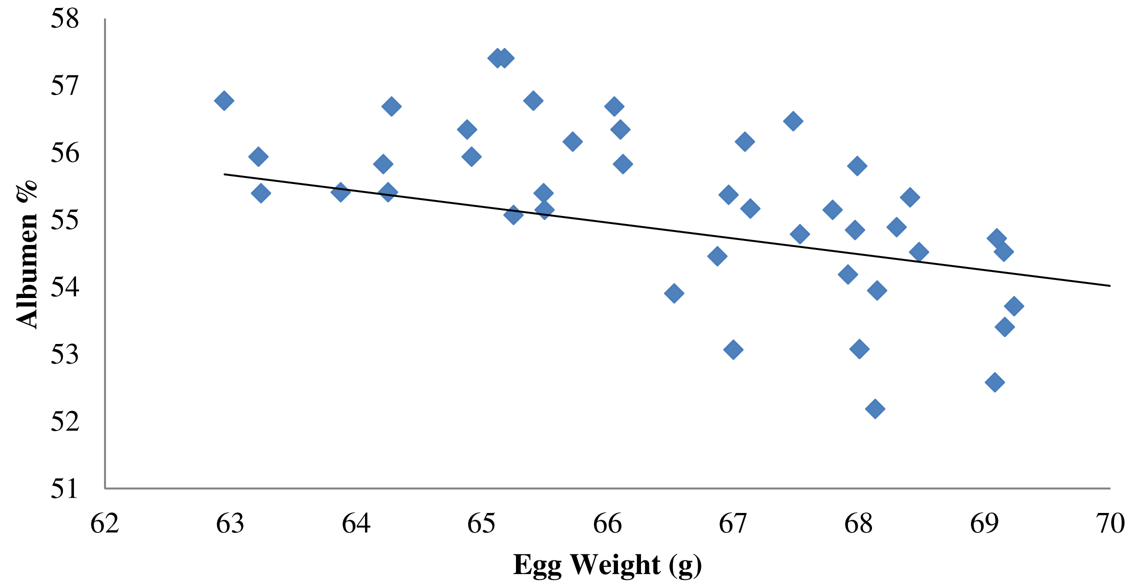

Figure 3.6 Relationship with albumen percentages and egg weight in broiler breeder egg from 37 to 60 weeks old.

There were no significant differences in GE between treatments at any age for yolk or albumen; however protein composition of the egg yolk increased significantly ($P<0.05$) with lysine intake at 37 weeks of age (Figure 3.7), where the formula was $y=0.001x + 30.18$ ($R^2=0.357$). Mean levels of protein in the yolk were 31.8, 31.4, 31.7 and 31.1 g per yolk/egg, respectively for birds with a daily intake of 1200, 1070, 930 and 800 mg lysine/ bird.day. This difference was not found at 45 or 60 weeks of age. Albumen protein composition remained constant between treatments at all ages.

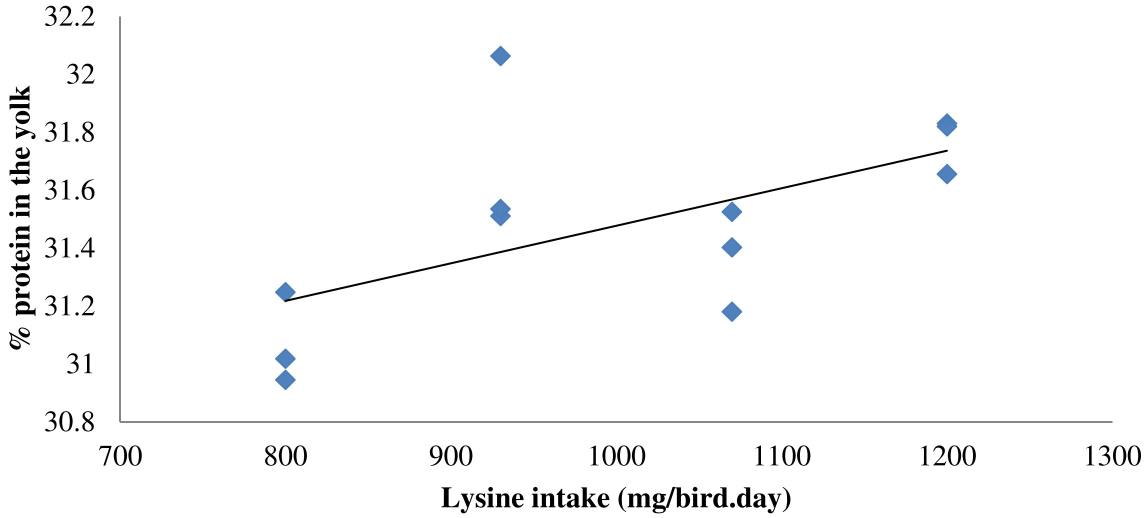

Figure 3.7 Protein concentrations in egg yolk from broiler breeder hens with different lysine intakes at 37 weeks of age.

3.3.2 Experiment 2

Broiler breeder hens at 52 weeks of age had significantly different BWs as a shown in Table 3.4. Birds receiving 1200 mg lysine per day had a greater BW than birds receiving 800 mg of lysine and the treatments with an increased and decreased levels of lysine in the diet, through the experimental period. However no differences were found in weight gain between treatments.

Table 3.4 Broiler breeder mean body weight (kg) through the experimental period.

Treatment	**Age (weeks)**			
(mg Lysine/bird/day)	37	45	52	60
1200	4.21	4.35	4.42^{a}	4.59
1200-800	4.13	4.24	4.21^{b}	4.42
800-1200	4.03	4.15	4.18^{b}	4.28
800	4.01	4.13	4.18^{b}	4.42
LSD[1]	0.21	0.21	0.18	0.24
P	0.288	0.216	0.026	0.178

[1] Least significant difference (P<0.05). $^{a-b}$ Means within a column with common subscripts are not significantly different (P>0.05)

Egg weight was significantly different at 37 and 45 weeks old (Table 3.5). Birds consuming 1200 mg of lysine per day showed the heaviest egg weight ($P < 0.05$) when compared to other treatments. However after 45 weeks of age, there were no significant differences in egg weight to the end of the trial.

Table 3.5 Mean egg weight (g) in broiler breeder hens fed different levels of lysine over time

Lysine intake	**Age (weeks)**			
(mg / bird.day)	37	45	52	60
1200	65.4^{a}	67.0^{a}	68.5	68.9
1200-800	64.5^{b}	65.7^{b}	65.7	67.6
800-1200	63.8^{bc}	65.5^{b}	68.2	68.6
800	63.5^{c}	65.5^{b}	67.1	68.4
LSD[1]	0.87	1.2	2.8	1.4
P	0.004	0.05	0.12	0.36

[1] Least significant difference (P<0.05). [a-c] Means within a column with common subscripts are not significantly different (P>0.05)

Broiler breeder hens showed a significant difference in egg output (Table 3.6) at 37 weeks old. Hens receiving 1200 mg lysine/ bird.day had the highest egg output. However, from 52 to 60 weeks of age, the birds on the lowest lysine intake (800 and 1200-800 mg Lysine/ bird.day) had the highest egg output.

Table 3.6 Mean Egg Output (%) in broiler breeder hens fed different levels of lysine over the period of 26 to 60 weeks of age

Lysine Intake	**Age (weeks)**			
(mg/bird/day)	37	45	52	60
1200	48.7^{a}	42.7	40.8^{a}	38.3^{a}
1200-800	35.5^{b}	38.1	42.9^{ab}	42.5^{b}
800-1200	44.6^{a}	41.2	41.0^{a}	36.2^{a}
800	36.7^{b}	39.2	45.1^{b}	42.3^{b}
LSD[1]	4.79	3.9	2.64	2.56
P	0.001	0.268	0.036	0.003

[1] Least significant difference (P<0.05). [a-b] Means within a column with common subscripts are not significantly different (P>0.05)

Shell thickness (Table 3.7) was affected by lysine intake at 60 weeks of age. Mean shell thickness was lower for birds fed decreasing levels of lysine towards the end of the production cycle

Table 3.7 Eggshell thickness (mm) in broiler breeders fed different levels of lysine in the diet, over age.

Lysine Intake	**Age (weeks)**			
(mg/bird/day)	37	45	52	60
1200	0.031	0.031	0.032	0.033[a]
1200-800	0.030	0.030	0.031	0.029[b]
800-1200	0.030	0.030	0.030	0.032[a]
800	0.032	0.031	0.032	0.033[a]
LSD[1]	0.001	0.001	0.001	0.001
P	0.268	0.268	0.118	0.001

[1] Least significant difference (P<0.05). [a-b] Means within a column with common subscripts are not significantly different (P>0.05)

Protein composition of the egg yolk was significantly affected by feeding treatment (P< 0.05). At 37 weeks (Table 3.8), with broiler breeders receiving low levels of lysine in the feed (800 mg/bird/day) showing significant lower protein content in the yolk. However, at 60 weeks (Table 3.9), birds that received increasing levels of lysine in the diet (800-1200 mg Lys) had significantly higher yolk protein content.

Table 3.8 Gross energy in yolk (GEy) and albumen (GEa); and protein in yolk (PTNy) and albumen (PTNa) in eggs from broiler breeder hens of 37 weeks of age.

Lysine intake	**37 weeks old**			
(mg/bird/day)	GEy	PTNy	GEa	PTNa
1200	31.9	31.8[a]	21.0	90.4
1200-800	32.1	31.6[a]	21.0	90.8
800-1200	32.3	31.6[a]	21.1	90.5
800	32.2	31.1[b]	21.2	90.6
LSD[1]	0.52	0.5	0.16	0.42
P	0.506	0.034	0.195	0.388

[1] Least significant difference (P<0.05). [a-c] Means within a column with common subscripts are not significantly different (P>0.05)

Table 3.9 Gross energy in yolk (GEy) and albumen (GEa); and protein in yolk (PTNy) and albumen (PTNa) in eggs from broiler breeder hens of 60 weeks of age.

Lysine intake	**60 weeks old**			
(mg/bird/day)	GEy	PTNy	GEa	PTNa
1200	25.6	30.5^{bc}	19.3	90.6
1200-800	26.3	31.0^{b}	21.0	91.1
800-1200	26.3	32.0^{a}	21.0	91.0
800	26.1	30.3^{c}	21.1	90.5
LSD[1]	1.3	0.7	2.52	0.54
P	0.604	< 0.001	0.449	0.111

[1] Least significant difference (P<0.05). $^{a-c}$ Means within a column with common subscripts are not significantly different (P>0.05)

3.3.3 Egg amino acid composition

The amino acid composition of the yolk only had a few amino acids affected by lysine intake. High lysine intake resulted in an increase in the levels of cysteine and histidine. However, high lysine intake resulted in a decreased level of serine in the yolk content. At 37 weeks old albumen proline content decreased with an increase in lysine intake, yolk histidine content increased when lysine intake was high; but other amino acids were not significantly affected by levels of lysine in the diet (Table 3.10)

At 60 weeks of age the amino acid content in the albumen was significantly different for tyrosine, aspartic acid, glycine, histidine, serine, valine and showed a strong tendency for arginine, leucine and proline. High lysine intakes increased the levels of tyrosine, arginine and histidine in the albumen, however high levels of lysine in the feed decreased the levels of valine, leucine, proline, serine, glycine and aspartic acid in the egg albumen (Table 3.11).

Table 3.10 Levels of amino acids in yolk and albumen from broiler breeders at the age of 37 weeks old

Amino acids	Units	37 weeks old							
		Yolk				Albumen			
		800	**1200**	***LSD*[1]**	***P***	**800**	**1200**	***LSD*[1]**	***P***
Protein	%	30.8	31.4	1.08	0.23	90.3	90.4	0.7	0.63
Cysteic acid	%	0.34	0.37	0.04	0.06	1.56	1.53	0.12	0.58
Methionine	%	0.83	0.9	0.09	0.12	3.57	3.62	0.09	0.27
Aspartic	%	2.83	2.78	0.25	0.65	8.04	9.2	2.76	0.36
Threonine	%	1.37	1.37	0.17	0.98	3.75	3.74	0.06	0.69
Serine	%	2.48	2.35	0.15	0.08	5.97	5.3	0.85	0.11
Glutamic	%	3.65	3.76	0.16	0.16	11.2	11.4	0.39	0.48
Proline	%	1.2	1.19	0.08	0.63	3.94[a]	3.64[b]	0.26	0.03
Glycine	%	0.85	0.85	0.05	0.79	2.96	2.94	0.09	0.57
Alanine	%	1.48	1.47	0.07	0.69	5.27	5.1	0.49	0.45
Valine	%	1.76	1.75	0.09	0.73	6.28	6.32	0.28	0.73
Isoleucine	%	1.48	1.51	0.08	0.41	4.31	4.35	0.25	0.73
Leucine	%	2.8	2.81	0.11	0.86	7.95	7.93	0.3	0.88
Tyrosine	%	1.24	1.26	0.05	0.41	2.73	2.79	0.13	0.27
Phenylalanine	%	1.27	1.28	0.06	0.71	5.21	5.22	0.18	0.97
Lysine	%	2.03	2.13	0.13	0.12	4.98	5.1	0.21	0.24
Histidine	%	0.67[b]	0.71[a]	0.03	0.02	1.80	1.84	0.06	0.11
Arginine	%	2.09	2.15	0.09	0.16	4.55	4.55	0.10	0.96

[1]Least significant difference (P<0.05). [a-b] Means within a row with common superscripts are not significantly different (P>0.05).

Yolk amino acid content was significantly affected by lysine intake for alanine, methionine, cysteic acid which increased with lysine intake. Proline and serine decreased in the yolk with an increase in lysine intake. There was a strong tendency for increased levels of isoleucine in the yolk with an increase in lysine intake.

3.4 Discussion

Protein and amino acids are the most expensive nutrients in broiler breeder feeds, with lysine often being the first limiting amino acid in these diets. Nevertheless the use of higher dietary amino acid concentrations or the increase in dietary protein levels may be justified and supported by an increase in the productivity of the flock.

Table 3.11 Levels of amino acids in yolk and albumen from broiler breeders at the age of 60 weeks old

		60 weeks old							
Amino acids	**Units**	**Yolk**				**Albumen**			
		800	**1200**	***LSD*[1]**	***P***	**800**	**1200**	***LSD*[1]**	***P***
Protein	%	30.1	31.0	1.68	0.24	90.3	90.1	0.77	0.53
Cysteic acid	%	0.35[a]	0.39[b]	0.04	0.04	1.83	1.77	0.14	0.31
Methionine	%	0.71[a]	0.79[b]	0.07	0.03	3.66	3.54	0.44	0.56
Aspartic	%	2.8	2.77	0.2	0.72	9.62[b]	9.10[a]	0.51	0.05
Threonine	%	1.13	1.11	0.13	0.72	3.26	3.13	0.24	0.24
Serine	%	1.95[b]	1.77[a]	0.15	0.02	4.91[b]	4.10[a]	0.47	0.01
Glutamic	%	3.88	3.8	0.19	0.31	11.9	11.7	0.50	0.28
Proline	%	1.39[b]	1.24[a]	0.13	0.02	3.40[b]	3.11[a]	0.35	0.09
Glycine	%	0.88	0.89	0.04	0.62	3.26[b]	3.11[a]	0.11	0.01
Alanine	%	1.41[a]	1.53[b]	0.12	0.04	5.12	5.39	0.46	0.20
Valine	%	1.88	1.92	0.1	0.36	7.43[b]	7.05[a]	0.38	0.05
Isoleucine	%	1.54	1.61	0.08	0.09	4.64	4.81	0.28	0.17
Leucine	%	2.83	2.83	0.14	0.99	8.50[b]	8.21[a]	0.32	0.06
Tyrosine	%	1.04	1.07	0.08	0.43	2.17[a]	2.41[b]	0.12	0.01
Phenylalanine	%	1.24	1.27	0.1	0.46	5.2	5.30	0.12	0.11
Lysine	%	2.21	2.13	0.14	0.19	5.28	5.18	0.24	0.40
Histidine	%	0.71	0.72	0.05	0.68	1.84[a]	1.93[b]	0.04	0.01
Arginine	%	2.02	2.08	0.14	0.42	4.40[b]	4.62[a]	0.25	0.07

[1]Least significant difference (P<0.05). [a-b] Means within a row with common superscripts are not significantly different (P>0.05).

3.4.1 Experiment 1

Increased lysine intakes may increase broiler breeder weight through the laying cycle. Previous research has found that increased levels of protein in the diet did not affect body weight as much energy intake did (de Beer & Coon, 2006). However, in this study, BW showed an increase up to 45 weeks old. Broiler breeders fed high levels of lysine throughout the trial showed a greater increase in BW when compared with broiler breeders fed lower lysine intakes, where at 45 weeks old breeders that were receiving 800 mg lysine/bird/day weighed an average of 4.13 kg and breeders that were receiving 1200 mg lysine/bird/day weighed 4.35 kg. Similar results have been reported by Harms & Ivey (1992) who concluded that breeders that consumed 938 mg lysine/bird/day were heavier than those consuming 848 mg/bird/day. Increases in BW with an increase in protein intake were also reported by Spratt & Leeson (1987) who found that BW was greater for breeders receiving 16.7% CP in the diet than breeders receiving 12.7% CP in the diet. However, after 45 weeks and until the end of production, BW between all treatments was not significantly different.

Because broiler breeder hens do not control voluntary feed intake to meet their requirements (Lee *et al.*, 1971), these birds need an intensive feed restriction program to control BW, which can greatly impact performance. Weight gain control in broiler breeders is crucial for productivity, where the excess of nutrients can lead in a high deposition of fat and consecutively in a decrease of egg production and fertility. Faulkner (1993) found that increased levels of lysine intake in broilers have a positive relationship with an increase in weight gain. However, in the present experiment this relationship was only observed when breeders were 37 weeks old, with a difference of 0.2 kg. Whether this increase in BW would affect production or mating activity cannot be answered from the results of the current trial. The coefficient of variation in BW should be considered to assess the real BW differences and how this will impact reproductive performance. In the current trial this was not measured. The differences between the results of the current trial and those of Faulkner (1993) could be explained by the fact that broiler breeders have a restricted access to feed while broilers have *ad libitum* feed intake and consequently the high lysine intake elicited a response in weight gain.

Lysine intake did not affect age at first egg, as birds in all treatments reached 50% egg production at 29 weeks of age. De Beer & Coon (2006) also found that protein intake did not affect the age at first egg. Egg production in broiler breeder hens reached a plateau and has a rapid decline in production after peak. However increased levels of protein and lysine intake did not alter or improve egg production in this experiment. Similar results have been reported by Joseph *et al.* (2000). In that trial, hens consuming 670 mg lysine/bird.day had a significantly lower egg production when compared with hens receiving 780 or 860 mg lysine/bird.day; however this difference disappeared when the birds were 29 weeks of age. In the present trial the low level of lysine intake of 800 mg, was not low enough to affect egg production.

Egg output was significantly affected by lysine intake and age. The higher EO at higher lysine intakes at 37 weeks of age showed that the requirements for lysine will increase to sustain egg output at peak of production; however hens at 60 weeks of age showed that an intake of 1200 mg lysine/bird.day could be in excess in the diet and so increase the production costs unnecessarily.

Broiler breeder egg weight increases as the birds age, and in this trial egg weight also had a relative increase with increased levels of lysine intake. Breeders that were fed 1200 mg lysine/day had heavier eggs than those consuming lower levels of lysine. The effects of protein intake on egg weight increases in broiler breeders was also reported by Butts & Cunningham (1972) where birds that were receiving high levels of protein in the diet had a greater percentage of large eggs than birds fed low levels of protein. Lopez & Leeson (1995a) found that broiler breeders at 30 weeks of age receiving 10 and 12% CP in the diet had egg weight 3 g lighter than birds receiving 16% CP in the diet; the same was observed by Joseph *et al.* (2000) who concluded that feeding broiler breeder hens from the age of 25 to 28 weeks, with 16% CP in the diet, had a positive impact on egg size when compared with birds fed at 14% CP in the diet. Heavier broiler breeder hens will lay heavier eggs (Tona *et al.*, 2001). This is in agreement with Kirikci *et al.* (2007), who found that heavier weight partridge breeders laid heavier eggs, compared with light weight partridge. The importance of large and heavy egg weight in broiler breeder production is understood, since large eggs are an indication of high chick BW at hatch (Shanawany, 1987) and this is a desirable trait in the broiler meat production industry (Abiola *et al.*, 2008). However, high BWs are not a desirable aspect for egg production, since birds that are overweight will have an excess of fat deposition, and may decrease egg production. As birds age, egg size increases, which can cause some complications at incubation, as the incubations trays cannot accommodate such large eggs, causing losses for hatcheries and broiler breeder producers.

The results show that the levels of lysine utilised in this trial were not sufficiently different to promote any change in egg production and egg output at any stage of the breeder's cycle. After 52 weeks of age, there were no significant differences in egg weight or BW; which supports the idea that 1200 mg of lysine at the end of the cycle is in excess and may be excreted as nitrogen by the organism (Lopez & Leeson, 1995a). Albumen and yolk weight were not affected by lysine intake. The increases in egg weight observed in this trial were related to age, with a proportional increase of albumen and yolk. This result is supported by Joseph *et al.* (2002) where dietary protein did not affect egg weight, albumen or shell weight. Gous & Nonis (2010) stated that egg protein components will remain constant through bird's life. However in the current study percentage of yolk protein showed a significant increase with higher lysine intake at 37 weeks of age, with this effect disappearing as the birds aged. It is possible to consider that the increase in egg weight, due to lysine intake at 37 weeks old, was due to an increase in yolk deposition, since increased protein in the diet will increase the amount of protein deposited in both, yolk and albumen (Gardner & Young, 1972). The lack of differences towards the end of the experiment could have been linked to the erratic ovulations and inconsistent laying pattern often observed in broiler breeder hens, giving the bird the opportunity to produce eggs of a certain composition in line with the statement of Gous & Nonis (2010).

3.4.2 Experiment 2

Feeding broiler breeders with increasing or decreasing levels of lysine in the feed may also affect BW; as observed in this trial, the constant high lysine levels, of 1200 mg lysine/bird.day, resulted in the heaviest BW at 52 weeks of age, compared with birds in all other treatments. Ciacciariello & Tyler (2013) proposed that higher lysine intakes in mature broiler breeder hens could have been well in excess of their requirement. If this is the case, then birds consuming the 1200 mg lys/bird.day would have been subjected to an imbalanced dietary energy: lys, resulting in higher BW at 52 weeks of age. The lack of significant differences in BW at 60 weeks could be explained by the reduced efficiency of utilisation that would have diminished the effects of the high level of lysine intake observed at 52 weeks.

Egg weight was significantly higher when birds were fed constant levels of 1200 mg lysine/ bird.day. The difference in egg weight could be seen in eggs laid by breeders from 37 to 45 weeks old. Egg output was increased at 37 weeks of age on birds fed constant levels of 1200 mg lysine/ bird day. However from 52 to 60 weeks of age, egg output increased in the treatments with birds fed 800 mg lysine/ bird.day and decreasing levels of lysine in the diet. Despite lysine intake not having a significant effect on yolk and albumen weight; it was possible to see differences related to the age of the hens. As the birds age, egg weight increases with a proportional increase in yolk and a decrease in albumen percentage (Gous & Nonis, 2010). A similar effect was found in the results shown in the Figures 3.5 and 3.6. Yolk protein at 37 weeks of age was significantly lower for birds receiving constant levels of 800 mg/ bird.day. Egg shell is mostly composed of calcium and deposition of calcium into the egg shell is affected by an interaction with protein (Romanof & Romanof, 1949). Consequently a deficiency in protein intake at this stage could affect calcium deposition into the egg shell, resulting in a poor shell thickness; however lysine intakes in the current trial were not low enough to affect shell thickness. The effects of feeding constantly low or decreasing levels of dietary lysine on shell thickness might indicate that broiler breeders receiving constant low levels of lysine from the beginning of egg production will need the same amount of amino acid intake, to supply their requirements for maintenance and egg production. Nonetheless, birds receiving a higher allowance of dietary lysine at the beginning of laying period may need proportional levels of lysine intake to supply their requirements for maintenance and egg production, responding negatively to decreasing levels of lysine in the diet, since the hens will use protein and amino acid intake for maintenance at the expense of egg production (Lopez & Leeson, 1994).

Since the birds received the same levels of energy in the diet it is possible to conclude that high levels of lysine in the feed can affect BW, egg weight and egg output, because high protein intake will increase the bird's skeletal frame (de Beer & Coon, 2006). However this difference may disappear as the bird's age and the large skeletal frame will require more protein and energy levels to supply their needs for maintenance, and thus will affect performance.

Gross energy in the albumen and yolk was also not affected by lysine intake, as was expected. Despite levels of CP in the albumen remaining unchanged by lysine intake; CP in the yolk was positively affected with increased lysine intake. An interesting observation made at 60 weeks of age was that birds that consumed increasing levels of lysine throughout the trial had the highest protein content in the yolk when compared with other treatments. This can be explained by the fact that at 60 weeks of age egg production was reduced and egg production will only occur if the albumen pool contains sufficient amino acids, therefore, the excess protein could have been deposited as yolk protein. Butts & Cunningham (1972) reported that increased dietary protein will increase whole egg protein content.

Researchers have supported the idea that protein and amino acid composition of the egg remains constant despite age and protein intake (Fisher, 1998). Birds fed the lower and the higher levels of lysine in this trial showed a significant difference in egg amino acid composition. However, those differences are inconsistent and do not appear to have a biological meaning probably owing to the small sample size. Vieira & Moran (1998) stated that yolk and albumen had a similar proportion of crude protein and amino acid throughout the broiler breeder life. If the bird is fed a protein-deficient diet, body muscle will be used for egg production unless the deficiency is too severe, in which case egg production would cease. Nevertheless in this trial the lysine intakes were not severe enough to decrease or even stop egg production. However due to the possibility in differences in amino acid composition of the egg occurring, this warrants future research in this subject to investigate the role of changes in amino acid composition and how this could affect embryonic growth and offspring.

CHAPTER 4
EFFECTS OF PROTEIN INTAKE AND FEED ALLOCATION ON EGG PRODUCTION AND FEED COST OF BROILER BREEDER ENTERPRISES

4.1 Introduction

Broiler breeder enterprises are one of the most challenging systems for producers and nutritionists alike. The use of feed restriction programmes is necessary to reduce the incidence of defective eggs and allow increased egg production, fertility and hatchability (Hocking *et al.,* 2002). Different types of feed restriction, such a qualitative or quantitative restriction, were proposed by researchers over the years (Bennett & Leeson, 1990; Robinson *et al*., 1993; Crouch *et al*., 2002). Qualitative feed restriction will provide birds with nutrients diluted in feed (Harms, 1979) or feed an appetite suppressant (Lee *et al*., 1971); whilst quantitative feed restriction will reduce feed intake to a certain amount given over a period of time (Lee *et al*., 1971). However there is a great deal of disagreement regarding the best level of feed restriction on which the birds will have optimum performance, without welfare being affected. Severe feed restriction applied in the rearing phase, where the chicks are growing and need high nutrient intake to support maintenance and growth can have negative effects on the future performance of the flock (Hocking *et al*., 2002). The incorrect feed intake management can lead to poor flock uniformity, which will depress productivity and performance during the laying phase (Fattori *et al*., 1991). Conventional feed restriction programmes can decrease daily consumption up to 60% to 80% of the *ad libitum* intake in the rearing period (Mench, 2002), 20% in early lay and up to 40% after peak of production (Hocking *et al*., 2002). Therefore, levels of protein and energy intake in broiler breeder must be well balanced to provide all necessary nutrients requirements. When most birds are fed an imbalanced feed *ad libitum*, they will consume more feed in order to meet the requirement for the first limited nutrient (McDaniel *et al*., 1981). When access to feed is restricted, as is the case with broiler breeder hens, this compensation mechanism is not possible and the bird will not be able to meet its requirements for maintenance and egg production. The optimum level of restriction, as well as the optimum dietary crude protein and energy content throughout the laying period are still very contentious points as these not only determine the success of the operation, but also determine the feed costs, which are one of the largest input costs. The aim of this experiment was to investigate how feeding different levels of crude protein intake on different feed allocations, throughout the production cycle, can affect egg production and feeding costs in broiler breeder enterprises.

4.2 Material and methods

4.2.1 Housing and management

Nine- hundred 20 weeks-old broiler breeder pullets and 90 Cobb 500 males were sourced from a local rearing farm and transferred to Ukulinga Research Farm, University of KwaZulu-Natal, Pietermaritzburg, South Africa. Photoperiod during rearing was maintained at 9L: 15D and a commercial feed restriction programme applied. Birds were placed in an open-sided house, which was divided in eighteen floor pens with a dimension of 3 x 3.5 m covered with wood shavings. Each pen was provided with line feeders with exclusion grids, male feeders, bell drinkers and nesting boxes with wood shavings. Artificial lighting was provided from the time the birds were moved, when photoperiod was increased to 14L: 10D. Natural light was supplemented with artificial lights between 5 and 7 AM and 4 and 7 PM. Initially, 50 hens were place in each pen. Five males were introduced in each pen when the hens had reached 10% egg production.

4.2.2 Experimental treatments

During the rearing period, birds were fed as recommended by the primary breeder. Feed allocation at 20 weeks was 110g feed/ bird.day and it was increased weekly by 10 g/ bird.day. By 26 weeks of age birds were receiving 160g feed/ bird.day. Experimental feeds were introduced at 26 weeks of age. The experiment ended when the birds were 60 weeks old.

Two basal feeds were formulated to provide a 12% (low) and 16% CP (high) diet (Table 4.1). These were blended to create a medium protein diet (14% CP) using a 1:1 proportion of the basal feed**.**

Table 4.1 Composition of high protein (HP) and low protein (LP) diets for broiler breeder

Ingredients		Diet	
	Units	**HP**	**LP**
Maize	g/kg	560	635
Wheat bran	g/kg	113	120
Soyabean full fat	g/kg	187	123
Sunflower 37	g/kg	64.0	43.0
DL-methionine	g/kg	0.50	0.10
vit + min premix	g/kg	1.50	1.50
Limestone	g/kg	65.0	65.0
Salt	g/kg	2.1	2.0
Monocalcium phosphate	g/kg	-	4.2
Sodium bicarbonate	g/kg	3.5	3.7
Potassium carbonate	g/kg	-	1.4

The basal feeds were mixed at a commercial mill and supplied to the birds in a mash form. Basal feeds were subjected to chemical analysis to determine their composition (Table 4.2). Moisture was determined 72 hours prior to the samples being freeze dried (Horwitz & Latimer, 2005); AME was determined through the Horwitz & Latimer (2005) method and crude protein was determined with a LECO FP 200 Nitrogen Analyser (Horwitz & Latimer, 2005).

Feed allocation, protein and energy content in the feed were changed through the experimental period to allow the birds to consume different levels of protein and energy throughout the 35 weeks of the trial. Treatment 1 had a constant protein concentration in the feed of 14% but decreasing feed allocation; treatment 2 had same feed allocation of 160g/ bird.day but decreasing levels of dietary protein concentration and treatment 3 had protein concentration and feed allocation changed through experimental period (Table 4.3).

Table 4.2 Nutrients analysed of the high protein (HP) and low protein (LP) diets for broiler breeders

Nutrients	Units	HP		LP	
		Total	**Avail**	**Total**	**Avail**
AMEn_adult	MJ/kg	12.0	-	11.7	-
EE	MJ/kg	10.8	-	10.9	-
Crude protein	%	16.6	-	12.4	-
Lysine	%	0.74	0.65	0.58	0.51
Methionine	%	0.32	0.29	0.25	0.23
Methionine+cystine	%	0.63	0.54	0.54	0.46
Threonine	%	0.59	0.5	0.5	0.42
Tryptophan	%	0.18	0.15	0.14	0.12
Arginine	%	1.05	0.93	0.85	0.75
Isoleucine	%	0.66	0.57	0.54	0.47
Leucine	%	1.43	1.3	1.29	1.18
Histidine	%	0.44	0.4	0.38	0.34
Phenylalanine	%	0.72	0.63	0.61	0.53
tyrosine	%	0.53	0.46	0.45	0.4
Phenylalanine+tyrosine	%	1.25	1.1	1.06	0.93
Valine	%	0.8	0.69	0.68	0.59
Ash	%	9.04	-	8.89	-
Crude fibre	%	4.54	-	4.06	-
Crude fat	%	6.14	5.26	5.24	4.53
Calcium	%	2.5	-	2.5	-
Avail. Phosphorous	%	0.25	-	0.25	-
Sodium	%	0.2	-	0.2	-
Chloride	%	0.18	-	0.18	-
Potassium	%	0.7	-	0.7	-
Linoleic acid	%	3.33	-	2.85	-
Choline	mg/kg	1206	-	1019	-

Levels of feed allocation and protein concentration changed at the beginning of each laying period. Treatment 1 received MP diet in all period, with a decrease in feed allocation from 175, 160 and 145 g/day, respectively for early, mid and late lay. Treatment 2 received 160 g/ bird.day throughout the whole laying period, with HP, MP and LP, respectively for early, mid and late lay and treatment 3 received diets MP, LP and MP and FA of 160,160 and 145 g/ bird.day respectively for early, mid and late lay.

Table 4.3 Change in feed allocation (FA), crude protein (CP) and energy content in dietary treatments for broiler breeder hens from 26 to 60 weeks of age

Period[1]	Early lay 26 - 38 weeks			Mid lay 39 - 49 weeks			Late lay 50 – 60 weeks		
Treatment	CP (g/d)	Energy (KJ/d)	FA (g/d)	CP (g/d)	Energy (KJ/d)	FA (g/d)	CP (g/d)	Energy (KJ/d)	FA (g/d)
1	25.3	2074	175	23.1	1896	160	21	1718	145
2	26.5	1920	160	23.1	1896	160	19.8	1872	160
3	23.1	1896	160	19.8	1872	160	21	1718	145

[1]Experimental period was divided into early lay, mid lay and late lay.

4.2.3 Data recording

All birds were group-weighed per pen at 26 weeks of age. Thereafter, 20 birds per pen were weighed once every four weeks. Mortality was recorded daily. Eggs were collected three times a day and separated into dirty, clean, and damaged eggs. The collected eggs were then kept in a refrigerated room and weighed three times a week. The cost of feed was calculated as the total of feed consumed kg/bird per period and the cost of each feed per kg.

4.2.4 Experimental design and statistical analyses

For research purpose and to show how broiler breeders can adjust to the levels of nutrient intake and feed allocation, the results of this trial were divided into three main periods, namely early lay (EL) from 26 to 38 weeks of age; mid lay (ML) from 39 to 49 weeks of age and late lay (LL) from 50 to 60 weeks of age.

To calculate the effects of feed allocation (FA) and protein intake on BW, weight gain (WG), egg production (EP) and egg output (EO), a completely randomised design was used, with three replications per treatment. In the current experiment cumulative crude protein and cumulative energy allowance were calculated for each treatment. Because each treatment had a different FA through each phase, protein and energy intake were changed accordingly; knowing the total intake by the end of the trial does help to understand the mechanism which broiler breeder hens use to partitioning nutrients for maintenance and egg production. To calculate CP intake, data for FA and CP were used. To calculate the cumulative crude protein intake data for the daily CP intake per broiler breeder was added throughout the trial. One-way analyses of variance GENSTAT 12th Edition (VSN International, 2009) was used to evaluate the effects of FA, dietary protein intake and feeding cost. Duncan's multiple range test was used to identify significant differences (P<0.05) between treatment means. Cumulative crude protein (CCP) intake was 5.5, 5.6 and 5.1 kg CP/ bird and the total energy consumed was 454, 452 and 437 MJ/ bird for birds on T1, T2 and T3 respectively.

4.3 Results

Mean BW, egg production, egg weight and egg output are presented in Table 4.4. Levels of protein, energy intake and feed allocation did not affect egg production, egg weight, egg output and weight gain during the EL period. However, EL period BW was significantly affected by dietary treatment (P<0.05). Birds on T1 had a heavier mean BW compared with birds on the other two treatments (Table 4.4). There were no significant differences in each of the variables in the ML period between dietary treatments. In the LL period there were significant differences in BW (P<0.05) due to dietary treatments; where birds on T1 and T2 had significantly heavier BWs compared with T3 (Table 4.4).

Egg production (rate of lay and number of eggs per bird), EW and EO were not significantly affected by dietary protein, dietary energy or feed allocation treatment, throughout the duration of the trial.

Feed cost was 19.3, 19.4 and 17.8 Rands/ kg respectively for T1, T2 and T3.

Table 4.4 Broiler breeder hens body weight (BW), weight gain (WG), egg production (EP), egg weight (EW) and egg output (EO) at different stages of the production cycle.

Age	TRT	BW (kg)	WG (g)	EP (%)	EW (g)	EO (%)
	1	3.78[a]	5.2	72.4	59.9	43.6
Early lay	2	3.6[b]	5.3	71.9	59.9	42.9
26-38 weeks of age	3	3.6[b]	8.7	72.0	58.3	41.9
	SED	0.07	3.24	2.7	1.46	1.29
	P	0.05	0.48	0.98	0.49	0.54
	1	3.88	0.9	52.6	67.2	35.3
Mid lay	2	3.85	2.5	56.3	67.3	37.9
39-49 weeks of age	3	3.82	1.4	57.7	65.9	38.0
	SED	0.06	2.83	2.36	0.08	1.45
	P	0.59	0.84	0.12	0.59	0.15
	1	3.95[ab]	2.14	46.4	69.5	32.2
Late lay	2	4.06[a]	5.57	45.4	69.8	31.7
50-60 weeks of age	3	3.87[b]	1.64	46.8	69.0	32.3
	SED	0.06	2.13	2.54	0.45	1.69
	P	0.02	0.17	0.85	0.26	0.93

[a-b] means within a column sharing a common superscript do not differ significantly. P > 0.05 not significant.

Table 4.5 Mean body weight gain (BWG), age at 50% production (ASM), rate of lay (ROL), number of eggs/hen housed (EP), egg weight (EW) and egg output (EO) of broiler breeder hens fed different protein and energy allocations from 26 to 60 weeks of age.

Treatment[1]	BWG (g/d)	ASM (d)	ROL (/100 hens)	EP	EW (g)	EO (%)
1	1.49[b]	204	57.2	136	65.2	37.3
2	3.33[a]	203	58.4	139	65.5	38.2
3	2.18[b]	205	58.5	139	64.0	37.4
P	<0.001	0.84	0.74	0.74	0.24	0.73
SED	0.29	3.39	1.87	1.80	0.78	1.07

[a-b] means within a column sharing a common superscript do not differ significantly. P > 0.05 not significant.

4.4 Discussion

The optimum level of feed restriction in broiler breeder hens is still a very contentious matter for poultry scientists and commercial nutritionist alike. The aim of this trial was to evaluate the effects of feed allocation and nutrient intake throughout the laying cycle in order to find the optimum nutrient intake which would optimise feeding management in broiler breeder female flocks.

In the present trial birds on T2 gained more weight (P<0.05) than those in the other treatments in spite of having similar cumulative energy intakes. Joseph *et al.* (2000) showed that the increase in BW during lay appeared to be due to fat deposition alone. Higher rates of lipid deposition would be expected to occur towards the end of the laying period when energy is supplied in excess of the requirement, this probably being the case with birds on T2. Body weight during the EL period was significantly different, where birds on T1 were significantly heavier (P<0.05). However, as the birds aged, this effect of dietary treatment disappeared. It is possible to conclude that birds on T3 received a lower nutrient allocation, but not low enough to affect egg production.

The higher protein intake for birds in T2 did not result in a higher performance. This finding is in agreement with de Beer & Coon (2006) who tested different levels of CP intake in broiler breeders, from rearing to end of production. Regardless of the difference in BW during the EL period, birds in all treatments had a similar BW by the end of production. Gous & Nonis (2010) have suggested that all weight gained by broiler breeders in the laying period would be the result of lipid deposition, and that no additional body protein is deposited, once the bird begins to lay. Despite the differences observed in BW between treatments in the EL and LL periods, there were no significant differences in egg output, rate of lay, weight gain and egg weight. Harms & Ivey (1992) concluded that 18.8 g CP/ day was sufficient to support egg production in broiler breeder hens between 45 to 48 weeks old. Lopez & Leeson (1995b) suggested that a protein intake of 16g CP/bird.day was sufficient to ensure egg production throughout broiler breeder reproduction phase.

The results of the current trial are in agreement with those of Joseph *et al.* (2002) who tested different dietary protein levels in broiler breeder diets from 19 to 32 weeks of age. In this report, feeding breeders with increased levels of 14.9 to 26.4g CP/bird.day and 15.1 to 28.8g CP/bird.day in the diet did not affect egg weight. Further reductions in dietary CP as reported by Joseph *et al.* (2000) showed that feeding broiler breeder hens, from 25 to 28 weeks of age, with 14% CP in the diet can greatly decrease EW and EP when compared with breeders on diet of 16 and 18% CP; where the average CP intake was 19.65, 21.75 and 24.57 g/day respectively for 14, 16 and 18% CP. The results of Joseph *et al.* (2000) are due to a very low protein intake, where in the present work, the lowest level of protein intake for the same period was 23.1 g/day being enough to support egg production and egg weight.

Although energy intake had a significant effect on BW, the extra energy consumed was not enough to elicit an increase in EW or EP. The results of this trial suggest that an energy intake of 1896 kJ/bird.day is adequate for broiler breeder hens from the onset of lay till after peak production. This value is similar to findings by Rabello *et al.* (2006) who recommended an energy intake of 1859 kJ/bird.day for broiler breeders at peak of production.

Fisher (1998) reported that the protein requirement during the laying period in broiler breeder hens is expected to remain constant, and it is unlikely that the daily protein allocation would need to remain the same. Because yolk production is a continuous process, and because egg production becomes more erratic as the laying period progresses, the efficiency of utilisation of protein for egg production appears to decrease significantly as egg production declines (Gous and Nonis, 2010) but this does not mean that protein intake should be increased as the hens get older.

The results of this trial suggest that female breeders did not benefit from the additional protein and energy provided during in the EL and ML periods by treatments1 and T2 (vs. treatment3), nor did they benefit from the additional energy provided in the final 10 weeks of production by T2. The overall cost of feeding these broiler breeders during the 34-week laying period was very similar for T1 and T2, whereas this was considerably lower (by 7.5 %) for T3.

Considering there were no significant effects of dietary treatment for EW, egg production and ROL; it is possible to conclude that during the EL and LL period, energy and protein intake can be reduced in broiler breeder diets, therefore reducing feed costs without affecting production. However further research in fertility and hatchability should be conducted to evaluate the nutrient levels proposed in this trial to ensure that these parameters are not affected by the lower levels of nutrient intake.

CHAPTER 5
GENERAL CONCLUSIONS

Ever since broiler breeder hens have needed a restricted feed intake to afford good performance, average nutrient intake from rearing to end of production, has always been a challenge for nutritionists. Similarly, selecting the correct feed allocation to ensure an optimum nutrient intake would be challenging for broiler producers, therefore minimal change in nutrient intake will be the differential between a profitable and non-profitable broiler breeder enterprise.

The objective of this trial was to study the performance response of broiler breeder hens, with different protein, lysine, amino acids and energy intakes, from start of lay until the end of production at 60 weeks of age. The results of current study showed that a constant lysine intake of 1200 mg lysine/bird.day will have an effect on BW, when compared with the lowest level in this experiment of 800 mg lysine/bird.day. However despite the higher BW, egg production and performance parameters were not affected by different levels of lysine.

The amino acid composition of the egg contents showed a significant variation, which could not be explained and it was attributed to the small number of eggs sampled. Further research needs to be done in this area especially considering genetic mechanisms that might be involved during the embryonic development.

The results in this study show that an energy intake of 1896 KJ/bird.day from the onset of lay until after peak of production was adequate to support maintenance and production and thereafter energy intakes can be decreased, since energy intake requirements will decrease as egg production decrease. With regards to dietary protein, an intake of 23.1 g CP/bird.day was sufficient to support egg production compared with higher protein intakes in this trial. The overall costing analysis for the different feeding programmes used in this study showed that feeding allocation with increased protein intakes, increased the cost of feeding up to 7% with no beneficial outcomes in production parameters observed. The economic evaluation shows the impact that relatively small changes in nutrient intake can have on the overall profitability of broiler breeder enterprises

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