The effect of different dietary levels of energy and protein on the production and body composition of broiler breeders

by

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Prof JP Hayes *March 2000*

Declaration

I, the undersigned, hereby declare that the work contained in this thesis project is my own original work and has not previously in its entirely or in part been submitted at any university for a degree.

JJP du Plessis *March 2000*

Abstract

THE EFFECT OF DIFFERENT DIETARY LEVELS OF ENERGY AND PROTEIN ON THE PRODUCTION AND BODY COMPOSITION OF BROILER BREEDERS.

by

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A flock of 500 Hybro broiler breeders were employed to study the effect of different levels of protein and energy on production and body composition. The daily lysine intake of the birds were 900, 1050, 1200 and 1350 mg respectively, each fed in diets with a daily energy intake of 1800 and 2000 kJ ME to provide a 4 x 2 factorial design. Lysine was used as the reference amino acid in the experiment and all other amino acids were kept in a constant ratio in every experimental diet. The total production was divided into 3 periods of 13 weeks each (week 23 - 35; week 36 - 48 and week 49 - 61) to determine the effect of the treatments over time. Production was evaluated by hen day production; egg weight (g/egg); egg mass (g/day); fertility; hatchability; chicks/hen/week; feed conversion and day old chick weight.

Hen day production was significantly (P < 0,05) lower at the high energy intake for period week 49 to 61. Energy and protein levels significantly increased egg weight. Effect of protein was consistent during all three periods of production. Egg mass output had a significant (P < 0,05) response to increasing levels of protein for the total period of production. The birds on the high energy diet produced a significant higher egg mass per hen during the first period of production (week 23 - 35). Hatchability was reduced (P < 0,05) by the higher energy intake for the total period of production and this effect was very significant (P < 0,01) during the final period of production. Similar to hen day production, the higher energy had a significant (P < 0,05) negative effect on the amount of chicks produced. The well-known correlation between egg weight and chick weight was confirmed with the regression equation: Chick weight = 10,5 + 1,22 x Egg weight. Both energy and protein had a significant (P < 0,01) positive effect on chick weight. The feed conversion was lower at increasing levels of amino acid intake (P < 0,01). Higher energy intake significantly (P < 0,05) increased hen weight and protein had a very significant effect during the first period of production (P < 0,01).

The isotope dilution technique (tritiated water) was used to estimate the body composition of the breeders. This was done at 5 different periods (week 27, 35, 43, 52 and 61) of the production period to establish changes in requirements over time. Significant correlation were found between carcass moisture and waterspace (R^2 = 0,76); fat % and carcass moisture (R^2 = 0,78); protein % and waterspace (R^2 = 0,35) and fat % and waterspace (R^2 = 0,46). The regression equations obtained from these correlation were employed to determine excess energy and lysine consumed at different ages. Energy requirements were calculated according to the effective energy (EE) system and the conventional ME system. According to effective energy the lower energy intake was not sufficient and the maximum requirement was calculated to be 1942 kJ EE/day. The metabolizable energy calculations indicated sufficient intakes at every treatment with the maximum requirement 1746 kJ ME/day. The lysine requirement was found to be in excess of 1050 mg lysine per day. The recommendation for daily lysine intake is 1200 mg/day and the energy intake of breeders should be 1900 to 2000 kJ ME/day from week 23 to 35 and can be reduced to 1800 kJ ME/day in the final period of production.

Samevatting

DIE EFFEK VAN VERSKILLENDE VLAKKE VAN ENERGIE EN PROTEÏEN OP DIE PRODUKSIE EN LIGGAAMSAMESTELLING VAN BRAAIKUIKEN TEELOUERS.

Deur

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Om die effek van verskillende vlakke energie en proteïen op produksie en liggaamsamestelling te ondersoek is 'n trop van 500 Hybro braaikuiken teelouers gebruik. Die daaglikse lisien inname van die henne was onderskeidelik 900, 1050, 1200 en 1350 mg, wat elk by 'n daaglikse energie inname van 1800 en 2000 kJ ME verskaf is, in 'n 4 x 2 faktoriale ontwerp. Alle aminosure is in 'n konstante verhouding met die verwysings aminosuur lisien in die rantsoen ingesluit. Om te evalueer of daar veranderinge oor 'n tydperk plaasvind weens die verskillende behandelings is die produksie periode in drie periodes van 13 weke elk verdeel (week 23 - 35; week 36 - 48 en week 49 - 61). Die produksie standaarde wat

gemeet is, is hen dag produksie, eiergewig (g/eier), eiermassa (g/dag), vrugbaarheid, uitbroeibaarheid, kuikens/hen/week, voeromset en dagoud kuikenmassa.

Hen dag produksie was betekenisvol ($P < 0,05$) laer by die hoër energie innames in die laaste periode van 49 tot 61 weke. Energie en proteïen het eiergewig betekenisvol ($P < 0,01$) verhoog. Die effek van hoër vlakke proteïen was konstant in alle produksie periodes. Die daaglikse eiermassa (g/dag) het ook saam met stygende vlakke proteïen verhoog en hierdie effek was vir die totale periode van produksie. Energie het die eiermassa in die eerste periode van produksie (week 23 - 35) verhoog. Uitbroeibaarheid is verlaag ($P < 0,05$) vir die totale periode van produksie deur die hoër energie inname en die effek was selfs groter ($P < 0,01$) in die finale periode van produksie. In ooreenstemming met die hen dag produksie is die aantal kuikens geproduseer negatief beïnvloed deur die hoër energie inname ($P < 0,05$). Die korrelasie wat bestaan tussen eiermassa en kuikenmassa is bevestig deur die regressie : Kuikenmassa = 10,5 + 1,22 x Eiermassa. Energie en proteïen het kuikenmassa betekenisvol ($P < 0,01$) verhoog. Voeromset was laer by stygende vlakke van proteïen inname ($P < 0,01$). Die hoër energie inname het henmassa ook betekenisvol ($P < 0,05$) verhoog en proteïen het dieselfde effek slegs in die eerste periode van produksie gehad ($P < 0,01$).

Die liggaamsamestelling van teelhenne is bepaal met behulp van die isotoop verdunnings tegniek (tritium water). Dit is bepaal op 5 verskillende stadiums in die produksie periode (week 27, 35, 43, 52 en 61) om die moontlike verandering in behoeftes oor tyd vas te stel. Betekenisvolle korrelasies is gevind tussen karkasvog en die waterspasie ($R^2 = 0,76$); vet % en karkasvog ($R^2 = 0,78$); proteïen % en waterspasie ($R^2 = 0,35$) en vet % en waterspasie ($R^2 = 0,46$). Die regressie vergelykings van hierdie korrelasies is gebruik om die hoevelheid surplus energie en lisien ingeneem te bepaal. Die "effective energy" sisteem en die konvensionele ME sisteem is gebruik in die bepaling van energie behoeftes. Volgens die "effective energy" was die energie inname nie voldoende by die laer energie innames nie en die maksimum behoefte is bereken as 1942 kJ EE/dag. Die maksimum energie behoefte volgens metaboliseerbare energie is bereken as 1746 kJ ME/dag. Die lisien behoefte moet hoër as 1050 mg/dag wees. Die aanbeveling van die daaglikse lisien inname is 1200 mg/dag en die energie inname moet 1900 tot 2000 kJ/dag wees tot 35 weke produksie en kan daarna verlaag word na 1800 kJ ME/dag.

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Chapter 1

1. INTRODUCTION:

The feeding of broiler breeder hens to meet correctly their nutrient requirements is probably the most complicated task that the poultry nutritionist faces. Improvements geneticists have made in broiler growth rates and feed efficiency have made the task of broiler breeder managers more difficult. The reason for this is due to a fundamental law of nature: The better the growth rate and feed efficiency of a class of animals, the poorer the reproductive performance. In general, we are sacrificing hatching egg production for improved broiler production traits. It has become an accepted practice to control body weight by restricting the amount of feed offered to the birds in an attempt to increase egg production. The nutritionist tries to ensure adequate intake of energy, protein and amino acids to optimize production.

There is a strong negative relationship between body weight and reproductive efficiency in domestic poultry (Robinson et al., 1993; Pearson & Herron, 1982). Reproductive efficiency in females can be classified by alterations to egg production (increased age at sexual maturity, poor rate of lay and termination of the laying period due to ovarian regression or death) and by alterations to chick production (the production of unsettable eggs, infertility and embryonic death). Breeder obesity is normally associated with poorer production, fertility, hatchability, livability and feed efficiency (Singsen et al., 1958; Sherwood et al., 1964; Costa, 1981).

Feed restriction of female broiler breeders during the rearing period have been shown to delay sexual maturity (Robbins et al., 1986; Wilson & Harms, 1986; Ingram & Wilson, 1987; Lee et al., 1971; Leeson & Summers, 1983), increase initial egg size (Blair et al., 1976; Leeson & Summers, 1983), decrease the number of double-yolked eggs (Fuller et al., 1969; Chaney & Fuller, 1975; Christmas & Harms, 1982; Hocking et al., 1989; Katanbaf et al., 1989b), increase livability (Lee et al., 1971; Wilson & Harms, 1986; Katanbaf et a.l, 1989a), increase fertility and hatchability (McDaniel et al., 1981a; Bilgili & Renden, 1985) and improve egg production (Leeson & Summers, 1983; McDaniel, 1983; Wilson & Harms, 1986; Hocking et al., 1987; Katanbaf et al., 1989b). These effects may also be influenced by photoperiod, temperature and other environmental factors that can alter the reproduction process.

In the following paragraphs a short survey will be given of reports from the literature on the effect of protein and energy levels on production parameters of broiler breeders.

2. PROTEIN REQUIREMENTS:

It is generally considered that energy intake is the major predisposing factor to body weight control. For this reason, the level of feed restriction is invariably adjusted to an estimated level of energy requirement. Under practical conditions this often means that broiler breeder hens are also subject to a considerable range of crude protein intakes. There is indeed also evidence to suggest that intake of crude protein per se in excess of requirement, is detrimental for hatchability (Leeson and Summers, 1991).

Independent of requirements for essential amino acids, protein requirements will be bound at the lower end by the total needs for nitrogen and at the upper end by any adverse effects of excess protein (Fisher,1998).

Estimates for requirements for egg production amounted to 20 - 22 g/day (Waldroup et al., 1976), 18 g/day (Marshall, 1977) and 21,8 g/day (Proudfoot & Hulan, 1981). Harms & Wilson (1980) also indicated that a diet containing 13,07 % protein was adequate for maximum production. Protein intake of 20,6 g/bird/day has been recommended for broiler breeders placed on litter (Wilson & Harms, 1984). At a feed intake of 150 g/bird per day, the diet would contain 13,7 % crude protein (CP).

Spratt & Leeson (1987) found no deleterious effects associated with feeding a 12,7 % crude protein diet to caged broiler breeders from 19 to 40 weeks of age. These workers concluded that caged broiler breeders can maintain normal reproductive performance through peak egg production when consuming 19 g protein and 1610 kJ ME per day.

Pearson & Herron (1982) indicated that the difference in performance and body weight gain could not be attributed to differences in protein allowance during lay. The absence of a protein effect at intake levels of 27,9; 23; 19,5; or 16,5 g/day suggested that the lowest protein intake was greater than the minimum required. It is possible to speculate that had protein intake been reduced further, an intake that was insufficient to support egg production and growth would have been reached and the effects of energy on performance would have become evident.

Bowmaker & Gous (1989) calculated the amount of dietary protein required for maintenance and growth of the reproductive organs of broiler breeders during the period of sexual maturity to amount to 10 g/day from the growth rate of the various organs during that time. Additional protein would be necessary at the onset of lay to meet the requirements for albumen formation.

Lopez & Leeson (1993) were convinced that breeder diets are over fortified with crude protein. They tested this theory by feeding birds 4 levels of protein (16, 14, 12 and 10 %) at an energy level of 12,14 MJ ME per kg. All diets contained similar levels of lysine and TSAA (total sulphur containing amino acids). Hen day production indicates that birds fed 16 % crude protein were the earliest to mature. Breeders fed 16 % CP produced most eggs at peak, and had the most persistent peak, although production declined more rapidly after 45 weeks of age. Birds fed 10 % CP performed well and peaked at 85 % and as with all other groups this occurred in week 33. Because of better persistency towards end of lay, birds fed 16 and 10 % CP produced comparable number of eggs.

Cave (1984) showed that, by feeding broiler breeders on a high protein diet from 19 to 26 weeks of age, egg production in the later laying period (35 to 50 weeks of age) was improved. Brake, Garlich & Peebles (1985), while confirming the beneficial effect of protein on hen day production, reported some reduced hatchability and increased embryonic mortality associated with the higher protein regimen. It is possible that other nutrients (vitamins and trace minerals) will have to be adjusted in formulating effective pre-layer diets. In both the above experiments the results were explained by assuming that the extra protein consumed had provided a reserve of protein from which the bird could draw at a later stage of production.

Broiler breeders, like all birds, do not require "crude protein" per se, but rather the essential amino acids that are the building blocks of such proteins. In practice it should be possible to replace crude protein with synthetic amino acids. The quality of dietary protein is determined by its amino acid content and the balance of it relative to overall requirement (Lopez & Leeson, 1994). It is difficult to dissociate the effect of the limiting amino acids especially methionine, lysine and tryptophan (Harms, 1992). Often dietary crude protein intake has been confounded with intake of limiting amino acids in studies involving egg production. While some researchers reported good production by broiler breeders with intakes of 27,7 g crude protein and 1272 mg of lysine/bird/day (Bowmaker & Gous, 1991), others report daily needs as low as 18,6 g crude protein and 1022 mg of lysine. Pearson & Herron (1981) reported that 19,5 g protein per bird per day was adequate provided that the essential amino acid ratios were in accordance with the so called ideal protein. Their diets supplied a minimum of 970 mg lysine and 570 mg methionine per bird per day.

Based on the results of their studies Wilson & Harms (1984) suggested that nutrient specifications for broiler breeders include daily intakes of 20,6 g protein, 400 mg methionine and 938 mg lysine. In 1982 Wilson & Harms found that a daily intake of 808 mg lysine and 18,6 g protein, supported maximum egg production and egg weight but not body weight.

Harms & Russel (1995) determined that a daily intake of 845 mg of lysine per hen was required for maximum egg production, egg mass and content. This is higher than the National Research Council's 1994 recommendation of 765 mg. A daily intake per bird of 18,07 g of protein was required when feeding a corn-soybean meal diet containing no supplemental amino acids. When both methionine and lysine were added to the diets, daily protein intakes of 15,53 and 16,37 per bird resulted in performance not significantly different from that of the controls on higher levels of protein.

Fisher (1998) concluded that total nitrogen requirements will be fully met by mixtures of practical ingredients that satisfy amino acid requirements. In conventional breeders an upper limit to protein of about 150 to 160 g/kg seems to be indicated although this will be higher and lower, respectively, in dwarf and large male-line breeders.

Two models for the calculation of protein and amino acid requirements for layers had been presented previously by Hurwitz & Bornstein (1973). The results with Model A and B applied to broiler breeder hens are in agreement with those of a previous study employing Leghorn and crossbred egg layers (Hurwitz & Bornstein, 1977). Bornstein et al., (1979) concluded, therefore, that the amino acid requirements of laying hens are functions of the four parameters' characters: rate of production, egg weight, body weight and weight gain, irrespective of type of bird. The calculated lysine requirements using Model A, was 980 mg/bird/day and using Model B 810 mg/bird/day. Waldroup et al., (1976) calculated protein needs using a modification of the equation reported by Hurwitz & Bornstein (1973). Using this equation Waldroup et al., (1976) calculated daily protein requirements for every week that reached a maximum of 15,8 g/hen/day at 34 weeks of age. Waldroup et al., (1976) also used Model B of Hurwitz & Bornstein (1973) to calculate daily amino acids needs but used the maintenance amino acid levels reported by Leveille et al., (1960). The daily lysine needs calculated in this manner reached a maximum of 773 mg/day at 34 weeks according to Waldroup et al., (1976).

Leeson & Summers (1991) suggested a lysine intake of 960 mg and a protein intake of 24 g/bird/day. Harms & Ivey (1992) suggested the daily lysine requirements for egg production to be 824 mg when protein intake was greater than 18,6 g/day.

Bowmaker & Gous (1991) used the diet dilution technique and the Reading Model to determine coefficients of response when incremental levels for lysine were offered to broiler breeders. On average, an individual broiler breeder weighing 3 kg and producing 45 g of egg per day would need 793 mg of lysine. These workers concluded that in the absence of accurate response data, and without the appropriate computer software, an estimate for the requirement of the average bird in the flock according to the Reading Model coefficients to amount to 793 mg of lysine per day. A safety factor of 20 % was added to this figure which brought the daily allocation to 952 mg of lysine per bird per day.

To summarize, the protein requirement of broiler breeders was found to be between 15,8 g/day (Waldroup, 1976); 16,5 g/day (Pearson & Herron, 1982); 18 g/day (Marshall, 1977); 18,07 g/day (Harms & Russell, 1995); 18,6 g/day (Wilson & Harms, 1982); 19 g/day (Spratt & Leeson, 1987); 19,5 g/day (NRC, 1994); 19,6 g/day (Pearson & Herron, 1981); 20,6 g/day (Wilson & Harms, 1994); 20,9 g/day (Harms & Wilson, 1980); 20 - 22 g/day (Waldroup, 1976); 21,8 g/day (Proudfoot & Hulan, 1980) and 24 g/day (Leeson & Summers, 1991). The dietary crude protein intake is influenced by the limiting amino acid intakes.

The lysine requirement of broiler breeders varied between 765 mg/day (NRC, 1994); 773 mg/day (Waldroup, 1976); 793 mg/day (Bowmaker & Gous, 1991); 808 mg/day (Wilson & Harms, 1982); 810 mg/day (Bornstein et al, 1979); 824 mg/day (Harms & Ivey, 1992); 845 mg/day (Harms & Russell, 1995); 893 mg/day for average and 1065 mg/day for a flock (Fisher, 1998); 938 mg/day (Wilson & Harms, 1984); 960 mg/day (Leeson & Summers, 1991); 970 mg/day (Pearson & Herron, 1981) and 980 mg/day (Bornstein et al., 1979).

Kleyn (1994) indicated that even under the most extreme conditions, little would be gained by supplying breeder hens with more than 1000 mg lysine per day.

Several workers have also investigated the effect of the protein level on fertility and hatchability. Fontana et al., (1990) found an improvement in fertility (4,2 %) by restricting feed consumption and thereby the body weight of broiler breeder males. There were however no significant differences in the percentage fertility for the two levels of dietary protein (12 % and 14 %). The body weight and dietary protein levels for the males had a minimum influence on semen concentration. These results are consistent with those of Vaughters et al., (1987) and of Wilson et al., (1987b). These researchers found that feeding broiler breeder males diets with 12 % versus 14 % protein or 12 % versus 15 % protein had no effect on semen concentration.

Hocking (1990b) compared the fertility of males fed on a low protein diet to that of males given the same higher protein breeder-ration as the females. The low protein diet (110 crude protein per kg) resulted in higher fertility after 42 weeks of age. Reports from caged birds have shown that more males stop giving semen at earlier ages on high protein diets compared with low protein rations (Wilson et al., 1987a & b; Hocking 1989). The blood plasma uric acid concentration suggest that males on the high protein diet were at a greater risk of developing articular gout.

Research data with both Leghorns and broiler breeders support the concept that high levels of crude protein result in greater embryo mortality, and thus lower hatchability. Lopez & Leeson (1993) have shown better hatchability for breeders consuming 19 g rather than 25 g crude protein per bird per day. The latter intake is not high by commercial standards, and is achieved at peak production with a diet containing only 17 % crude protein. Lopez & Leeson (1993) found that there was a consistent improvement in hatchability when birds were fed a low protein diet. Hatchability of all eggs improved linearly with decrease in crude protein, with birds fed 10 % crude protein having around 88 % hatch of set. Hatch of fertile was also improved with low protein diets although the effect was less dramatic. This data indicates that the major advantage to low-protein diets is improved fertility, rather than improved embryo survival may relate to greater control over body weight (Lopez & Leeson, 1993).

Hocking (1990b) also found that when body weight is controlled by food allocation, an optimum intake exists for maximum fertility and that the control of male body weights by separate-sex feeding can lead to a significant improvement in fertility at all ages.

On regulated feeding systems in broiler breeders, the balance between protein and energy intake can have a marked effect on hatchability. When the protein and energy intake is high, hatchability was found to be depressed. This is particularly noticeable when egg production is high and energy intake is low (Reddy, 1993).

Pearson & Herron (1981) found that relatively high protein intakes (27 to 28 g/bird/day) had a detrimental effect on hatchability when energy intake was low (1520 kJ AME per bird per day). This effect was not observed when energy intake was in excess (1880 kJ AME per bird per day) or when intakes of 21,3 g/bird/day were given. These workers therefore found that in birds kept on litter, hatchability was depressed when the protein : energy ratio was greater than 15 g : 1 MJ although there was no depression of egg production even at the highest ratio (18 g : 1 MJ). This limit (15 g : 1 MJ) was also confirmed by Whitehead et. al., (1985). Leeson & Summers (1991) also found reduced hatchability when breeders were fed low energy, high protein diets, and that chick viability may also be affected. Spratt (1987) confirmed this observation, and subsequently showed that breeder nutrition does in fact have an effect not only on hatchability and day-old chick weight, but also early growth rate of their broiler chicks. In this study, individually-caged broiler breeders were given daily intakes of 19 versus 25 g crude protein (low versus high) and 1360, 1611 or 1883 kcal ME per kg (low, medium and high). There was a consistent trend for the high protein intake to reduce egg production, while energy intake was positively correlated with egg production. Although not significant, increased protein allowance depressed hatchability, while the converse was seen with increased levels of energy.

Leeson & Summers (1991) showed that although high protein levels (25 g/bird/day) seemed to improve egg size, most other traits of commercial significance were adversely affected. Although the term "high protein" is used to describe these treatments, diet protein equivalents are not excessive in relation to commercial practice. Thus to achieve a "high" protein intake of 25 g/bird/day, a flock of breeders consuming 160 g/bird/day would achieve this intake with a diet protein content of only 15,7 %. A comparable protein intake by Leghorns consuming 100 g per bird per day would be achieved with a diet level of 25 % crude protein. Obviously the breeder hen requires more protein than does the Leghorn for maintenance, although with a 1 kg body weight difference this should amount to only 3 g/bird/day. If these calculations are correct, then we are over-feeding the breeder by some 5 g crude protein per day.

3. ENERGY REQUIREMENTS:

As the protein levels of most commercial breeder diets are well in excess of requirements, it is safe to assume that the producer is allocating feed principally to meet the bird's requirement for energy. This is borne out by the fact that if large increments of feed are withdrawn from a flock of birds, production often falls immediately, despite the fact that the protein requirement is still exceeded. The ideal is to ensure that a flock receives an adequate energy allocation without too much protein, as this may cause the birds to be overweight with all of the associated problems.

Spratt & Leeson (1987) found that broiler breeders are most responsive to energy intake as energy is usually the first limiting nutrient for the breeder hen. Energy requirement is the total of needs for:

1. Body Maintenance and Activity (50 % to 75 % of the daily energy intake)

2. Growth (5 % to 30 % of intake)
3. Egg Production (1 % to 35 % of intake)

Although producers are interested in egg production and the associated energy required, the majority of a hen's energy is needed for maintenance. Only about one third is available for production. Maintenance requirements are not constant and are affected by many factors (Balnave, 1974). The absolute energy intake at which optimal egg numbers occur will therefore depend primarily upon actual maintenance requirements.

If a hen gains a sufficient amount of weight during a given week, requirement for maintenance, growth and egg production has been met. The weekly weight gain of the flock through peak egg production thus correlates to the energy status of the flock (Boren, 1993). In full fed layer flocks, birds have the chance to adjust their individual feed intakes in order to meet the specific energy requirements. However with controlled feeding of heavy broiler breeders meeting the energy requirements of the birds is up to the poultry-man. The birds eat what they are given and therefore must be fed accurately.

For the estimation of energy requirement, Combs (1968) developed an equation which takes into account the environmental temperature, body weight, body weight change and daily egg mass. Waldroup et al., (1976) calculated, using the equation of Combs (1968), that the maximum energy need at 24 °C was 1747 kJ ME/day at 34 weeks of age. This level decreased over time and was 1536 kJ ME/day at 64 weeks of age.

Costa (1981) suggested a similar equation for the estimation of energy requirement. Costa illustrated that at a given temperature the total requirement for maintenance, plus body weight gain is almost constant between 24 and 36 weeks of age. This was because body weight increased but at the same time there was a decrease in body weight gain. This is important because it shows that at a given temperature, the primary factor in the variation of the overall energy requirement must be the rate of production. He concluded that the total daily energy needed by a broiler breeder at 30 weeks of age with a weight of 3 kg, a daily weight gain of 10 g/day, and a egg output of 56,8 g/day is 1862 kJ ME/day per bird at 18 °C.

Van Wambeke (1977) observed that 1880 kJ apparent ME (AME) per bird per day gave the highest performance and highest gross profit from Ross and Hubbard strains of broiler breeder in a temperate climate. Scott (1975) estimated the energy requirements for broiler breeders to be 1760 kJ AME per bird per day for temperate and 1590 kJ AME for hot climates. Pearson & Herron (1981) found that an energy allowance of 1520 kJ AME per day was not enough to meet the birds energy requirements for egg production. Van Wambeke (1977) found that the rate of lay decreased as the daily energy allowance was increased to 1880 kJ AME per day. A likely explanation is that the extra energy enabled the birds to gain more weight and that this had a depressing effect on egg production. Most of the difference in body weight between birds on the 1880 kJ AME allowance and those on the 1780 kJ AME allowance could be accounted for by differences in the amount of body fat present in the bird.

Wilson & Harms (1986) found that an average daily consumption of 2093 kJ ME per bird per day during lay resulted in significantly higher production than a " standard" feeding regimen of 1674 kcal ME per bird per day. However, Spratt & Leeson (1987) concluded that 1611 kJ ME per bird was sufficient to maintain normal performance through peak production.

Lopez & Leeson (1993) indicated that the energy requirement of adult broiler breeders is between 1778 - 1988 kJ ME per day. Robbins et al., (1988) also indicated that a broiler breeder needed 2092 kJ per day to reach maximum production.

A consistent observation in experiments is that restriction of energy intake leads to improved viability. In some cases the mortality rate of ad libitum fed hens has been 5 % higher for a given productive cycle, though 1 to 3 % is more usual (Snetsinger & Zimmerman, 1974). The basis for this improved viability could be ascribed to several causes. Polin & Wolford (1973) suggest that limited feeding may reduce the incidence of fatty liver haemorrhagic syndrome although no direct evidence was presented to support this suggestion. Bish et al., (1985) found that the small and medium birds had a higher livability than did the heavy birds. By 64 weeks of age, the livability of the heavy birds was 13,4 % and 12,3 % significantly less than for the medium and small birds respectively. There is a substantial difference in livability and could increase the cost of production for the heavy birds.

Regulation of the daily energy intake from 1860 kJ ME per bird to 1490 kJ ME per bird was associated with a reduction in mean egg weight, although number of eggs laid and hatchability were not significantly affected.

Pearson & Herron (1981) indicated that as energy intake increased, egg numbers increased until the birds energy requirement for production was met (in this case at 1610 kJ AME per day). No further increase in egg numbers occurred as energy intake increased from 1610 to 1880 kJ AME per day. The tendency for egg numbers to decrease as energy intake increases beyond requirements was therefore not observed as in previous experiments (Pearson & Herron, 1980). It is possible to speculate that such a decrease would have occurred had the energy allowance been increased further. The decrease in egg numbers, as the energy allowance was decreased from 1610 to 1130 kJ AME per day, appeared to be due to an increase in the number of birds out of lay for periods of 7 days or more, as well as a reduction in the number of birds laying on more than 3 days in the week. These findings suggest that when energy is limiting the broiler breeder hen tends to lay shorter sequences of eggs and more frequently goes out of lay for periods of more than 7 days.

Bornstein et al., (1979) found that restricting the daily energy intake to 1841 from 1891 kJ per hen had no effect on the rate of production. On the other hand, egg weights decreased by 1 to 2 g/egg. A further reduction in energy intake to 1720 and 1700 kJ per day respectively, resulted in a decrease in the rates of production by 5 and 6 percentage units, without any consistent effect on egg size. It appeared, therefore, that the energy for broiler breeder hens (weighing 3200 - 3800 g) for peak production was approximately 1841 kJ per day or slightly less, if the criterion is the rate on production. This daily energy need compares well with the range of 1778 to 1883 kJ per day suggested by Waldroup & Hazen (1976). On the other hand, the negative response of egg size to even slight energy restrictions is in contrast to the results of Chany & Fuller (1975). In the case of egg strain layers the special susceptibility of egg weights to energy restriction has been encountered (Snetsinger & Zimmerman, 1974).

Energy requirements depend not only on productive performance, body weight and weight gain but also on ambient temperature. During cold weather the hen utilizes more of her energy intake for maintenance of body temperature, leaving fewer calories for egg production.

Bornstein et al (1979) used the following two equations to calculate the energy requirements (ER).

ER (kcal/hen/day) = $145\ W_1^{\ 0,67} + 2G + 1,8\ EM$

Hurwitz & Bronstein (1977)

ER (kcal/hen/day) = $(1,78 - 0,012T) \times 1,45\ W^{\ 0,653} + 3,13\ G + 3,15\ EM$

Combs (1968)

where : T is temperature in degrees F

W_1 is body weight (kg)

W is body weight (g)

G is weight gain (g per day)

EM is egg mass (g per day)

If one calculates the actual energy restrictions used successfully, these calculations overestimate the empirical results by 9 % and 2 % respectively. Spratt & Leeson (1987) indicated that broiler breeders are less able to metabolize dietary energy than Leghorn birds. Regardless of diet specifications, it would appear that broiler breeder birds metabolize some 2,5 % less energy from feeds than do Leghorns. This relates to some 293 kJ for most breeder diets. Since tables concerning ingredient composition usually contain ME values determined with White Leghorns, further research is therefore needed if energy requirement of broiler breeders is to be accurately estimated. This work also indicates the importance of determining strain specific ME values in energy balance studies. Sibbald (1976) found no strain differences by using either roosters, laying hens, turkey hens or broiler breeder hens during a true metabolizable energy assay of a complete diet.

Spratt et al., (1990b) confirmed the results of Johnson & Farrell (1985) that broiler breeder hens require less energy daily for maintenance than egg-type hens. Broiler breeders are similar to other species concerning the ME-cost of protein deposition, but appear to be more efficient with respect to body fat deposition and egg production. Spratt et al., (1990) found that the energy requirement of 28 to 36 week old Hubbard broiler breeder hens for maintenance was 292 kJ per kg of live weight (360 kJ per kg 0,75 per day). This was not statistically higher than the earlier value of 266 kJ per kg per day (365 kJ per kg 0,75 per day) reported by Johnson & Farrel (1985) for caged Hyline broiler breeders 42 to 49 weeks of age. The efficiency of using AME for body and egg-energy retention combined was 0,817 which was higher than the value of 0,7 reported by Johnson & Farrel (1985).

Recalculation of growth data from Hubbard broiler breeder hens (Spratt & Leeson, 1987) suggest that the optimum empty BW gain from 28 to 40 weeks of age was 2 g to 3 g per day. The extra AME required for a growth rate of 3 g per day was calculated to be 94 kJ per bird per day. Therefore a 3,5 kg broiler breeder hen at 85 % egg production and gaining 3 g of body weight per day would require 1600 kJ of AME per day.

To summarize, the energy requirement of broiler breeders was found to be between 1590 kJ/day (Scott, 1975); 1610 kJ/day (Pearson & Herron, 1982); 1611 kJ/day (Spratt & Leeson, 1987); 1730 kJ/day (Pearson & Herron, 1981); 1747 kJ/day (Waldroup, 1976); 1760 kJ/day (Scott, 1975); 1778 - 1883 kJ/day (Waldroup & Hazen, 1976); 1778 - 1988 kJ/day (Lopez & Leeson, 1993); 1808 kJ/day (Spratt et al., 1990); 1841 kJ/day (Bornstein et al., 1979); 1862 kJ/day (Costa, 1981); 1880 kJ/day (Van Wambeke, 1977); 2093 kJ/day (Robbins, 1988) and 2093 kJ/day (Wilson & Harms, 1986). Each of these results would depend on the size of the hen, the daily weight gain, egg production and environmental conditions as well as a few other variables but still give a good indication of the requirement of broiler breeders to optimize production.

Under restricted feeding systems, when the bird is unable to adjust its energy intake to meet changes in maintenance requirements, a method of assessing the adequacy of an energy allowance is needed. Body weight, since it is linearly related to energy intake, would seem to be a good criterion. The close relationship between energy allowance and egg number and between energy allowance and body weight mean that changes in body weight gain, particularly in the early part of lay, can be a useful guide to the efficient production of hatched chicks. Pearson & Herron (1980) suggested that more attention should be paid to body weight changes during lay to estimate energy requirements. Flocks should be weighed weekly up to 35 weeks and at least every other week of their lives. A plateau in body weight indicates that hens have not received enough energy and a loss in egg production can most likely occur within 7 - 10 days after hens have stopped gaining body mass.

Most of the body weight gain occurs in the early part of the laying period. Minimum daily energy allowance giving maximum egg production (1610 kJ AME per bird) was associated with a mean body weight gain of 1,12 kg to 1,19 kg from 21 to 36 weeks of age at 4 different protein levels (Pearson & Herron, 1982). This is in close agreement with previous observations by Pearson & Herron (1981) who found on litter a mean body weight gain of 1,1 kg from 21 to 36 weeks of age which was associated with an optimum number of eggs. The energy allowance was 1730 kJ AME per day. The absolute amount of energy required to achieve this gain differed presumably since maintenance requirements were lower for birds kept in cages because birds gaining 1160 g body weight from 22 to 36 weeks received 1883 kJ per day per bird and became excessively fat. This did not seem to reduce egg production or hatchability up to 40 weeks (Spratt & Leeson, 1987).

Genetic differences exist for the minimum age (Leeson & Summers, 1983) and minimum weight (Brody et al., 1980) for the onset of sexual maturity. The onset of sexual maturity occurs at heavier body weights in females from rapidly growing lines than in those from slower growing lines. It seems that the minimum weight for such onset of sexual maturity in a particular line is difficult to change nutritionally. One hypothesis however is that minimum body weight for the onset of sexual maturity is controlled energetically, that is, by the absolute rate of energy intake relative to body weight. Bornstein & Lev (1982) found that earlier maturity and higher egg production were associated with higher energy intake during the pre-lay period. However lean body mass (Brody et al., 1980) and body composition requirements are also evident.

Body weight at onset of egg production and throughout the production year influences the efficiency of egg production. Birds with lighter body weights produce lighter eggs (Benoff & Renden, 1980; Madrid et al., 1981; Harms et al., 1982; Singh & Nordskog, 1982; Ruiz et al., 1983; Summers & Leeson, 1983; Bish et al., 1985), consume less feed per day and convert feed to egg mass more efficiently in comparison with heavier birds (Madrid et al., 1981; Harms et al., 1982; Singh &

Nordskog, 1982; Ruiz et al., 1983), this was found to be significantly lower for lighter birds (Summers & Leeson, 1983).

Lilburn & Myers-Miller (1990a) investigated the effect of body weight on early production of broiler breeders. The high body weight hens produced significantly more ($P < 0,002$) total and settable eggs than low body weight hens between 24 and 32 weeks of age. The low body weight hens body weight was about 15 % lower than the high body weight hens at sexual maturity on 24 weeks. Other results also indicate that ad libitum feeding during the early stages of production improves production over that obtained with various controlled feeding treatments (McDaniel, 1983; Robbins et al., 1986, 1988).

Wilson et al., (1983) reported that feed restriction resulted in higher fertility, hatchability and egg specific gravity, but that decreased egg production occurred in cold weather, if proper adjustments in feed allowance were not made. According to McDaniel et al., (1981a) restricted feeding of broiler breeders resulted in increased egg production, fertility, hatchability and egg specific gravity but decreased egg and chick weight when compared to birds fed ad libitum. Ousterhout (1982) noted that over-restriction of feed reduced egg production, whereas overfeeding reduced fertility but increased egg and chick weight. Feed restriction, therefore, should be done carefully to assure adequate intake of critical nutrients.

McDaniel et al., (1981a) also found that at 32 weeks of age body weight was negatively correlated with fertility, hatchability and hen day production. At 40 and 53 weeks these correlations increased or stayed the same. Body weight was positively correlated with egg weight.

Bootwalla et al., (1983) found that egg weight was significantly higher when broiler breeders were fed ad libitum instead of a single feeding. Skogland et al., (1952) found that broiler-chicks from eggs weighing less than 50 g are not as profitable as chicks from larger eggs.

There are few reports detailing the effect of breeder nutrition on the growth of broiler offspring. Increasing the protein or energy intake of broiler breeders increases egg weight (Pearson & Herron, 1982; Spratt & Leeson, 1987) and egg weight is positively correlated with chick weight (McNaughton et al., 1978). Hatching egg weight can influence subsequent body weight of broiler chicks up to slaughter (Proudfoot & Hulan, 1981) while chick weight can influence body weight of commercial egg-type pullets at 12 and 18 week of age (Deaton et al., 1979). Chick weight is normally in the range of 62 - 76 % of initial egg weight. A 1 g change in egg weight has been shown to result in a corresponding change of 2 - 13 g in broiler weight at 6 - 8 weeks of age (Reddy, 1993). Godfrey & Williams (1952) found that 74 % of the observed variation in body weight at market age is accounted for by size of the egg from which the chick is hatched, age at sexual maturity and mature body size. The size of the egg from which the chick was hatched exerted by far the greatest influence.

Spratt (1987) also monitored the effect of energy and protein on chick weights. These results showed that high protein levels are detrimental to most performance parameters, especially when used in association with lower energy intakes. There was a clear trend for improved performance with the higher energy intakes (1883 kJ ME/day), and this effect was carried over into broiler offspring. Breeders fed the highest (1883 kJ ME/day) energy allowance produced significantly heavier male offspring at 20 days, with the effect being some 4 % of an advantage at 41 days. These findings indicate the importance of adequate energy intake by the breeder, not only in terms of breeder performance, but also of early growth rate of offspring.

McNaughton et al., (1978) did confirm that the age of parents has an influence on the offspring's mortality because higher mortality occurred in chicks hatched from 29 week-old breeder eggs as compared to 58 week-old breeder eggs when egg weights remained the same. Therefore, a more viable chick was apparently produced from 58 week-old breeders. Higher mortality was also observed when chicks were hatched from 29 week-old breeder eggs weighing 47 - 54 g as compared to eggs weighing 57 - 62 g. Chick weights at hatching increased as hatching egg weights increased. No differences in one-day-old chick weights were found due to age of parents when egg weights remained the same. Therefore results indicate that age of parents have no influence on chick weights. These results agree with findings of Gardiner (1973). Wiley (1950) found chick size to be limited significantly by the space in the egg shell during the last 2 or 3 days of incubation. Therefore, it seems logical that only hatching egg size limits chick weights at hatching and not age of parents.

Significantly larger market weights of females were found when chicks were hatched from eggs weighing either 57 - 62 or 67 - 74 grams when compared to eggs weighing 47 - 54 g.

The objective of this thesis is to present nutritional strategies to help balance the lower potential for egg production against the economic necessity of maximizing viable hatching egg production and minimizing cost. Special emphasis will be paid to the daily requirement of protein (amino acids) and energy of the broiler breeders.

Chapter 2

THE RESPONSE OF BROILER BREEDERS TO DIETARY ENERGY AND AMINO ACIDS

1. INTRODUCTION:

In Chapter 1 an overview was given of factors that influence energy and amino acid requirements of breeders. The empirical approach by researchers to estimate requirements makes it extremely difficult to formulate diets that will supply the daily requirements of energy and amino acids of the broiler breeder at all times. Production rate and maintenance requirements are two of the most important factors influencing requirements. When either of these decrease, without a concurrent decrease in energy and amino acid intake, the surplus energy or amino acids deposited as fat, leads to a further drop in production. "Requirement" is defined as the quantity of a nutrient that should be absorbed by a normal healthy animal given a completely adequate diet, in an environment compatible with good health in order to meet its needs for maintenance and for a stated rate of production or for reproduction. Requirements are therefore age and species specific and also depend on other factors such as climate, disease status, stress and various production parameters (Lee, 1984).

Morris (1983) argues that the objective of quantitative experimentation should be to define the rate at which animals will respond to incremental inputs of a given amino acid. With this information, together with knowledge of the relative costs of input and value for output, it is possible to calculate an optimum allocation of the nutrient for a population. However, this philosophy is not appropriate when considering broiler breeders as the cost of the input (amino acids and protein) are slight when compared to the value of the output which is the amount of day old chicks produced. Hence, the aim of the researcher when working on broiler breeders, is to establish which level of lysine and protein intake will result in maximum egg production and subsequently day old chicks (Kleyn, 1994).

Although good scientific data exist for calculating the optimum daily intake of amino acids for broiler breeder hens, breeding companies are apparently reluctant to base their recommendations on such values. The present experiment was therefore designed to evaluate to what extent the breeder company's recommendation correlated with the actual needs of the birds under the local conditions.

Bowmaker & Gous (1991) feel that one of the major shortcomings generally found in nutrition trials in which broiler breeders are used is that such experiments are almost invariably conducted on groups of birds, and not on individuals. Because of the excessively high intakes of food by broiler breeders, relative to their requirements, it is customary to restrict their daily allowance to an amount less than that which would normally be consumed if the birds were allowed free access to food throughout the day. This practice inevitably leads to competition at the feed trough, with unequal quantities of nutrients being consumed by individuals in the group, the amount not necessarily being related to the requirements of the bird, but more often to the position of the bird in the social hierarchy. To overcome this difficulty when conducting research with heavy breeders, birds should ideally be housed individually in cages and be fed exact quantities of food each day. Under the conditions of the present experiment however, this was not possible as appropriate cages were not available.

The advantage of using groups of birds, is that it enables one to work with a larger number and in situations similar to industry. The population response continue to increase beyond the output for the average individual, hence the amount of amino acid required by the average individual in the population will always be less than the optimum intake of the population as has been discussed by Fisher et al., (1973) and by Morris & Blackburn (1982).

It is important when designing an experiment that all the food presented must be consumed by broiler breeders to be able to calculate accurately the amount of the nutrients consumed daily.

The theory of food intake regulation suggests that a bird will increase its voluntary food intake when the concentration of a nutrient in an otherwise well balanced diet is decreased. Daily food intake cannot increase indefinitely, being constrained by the density of the food and by the need of the animal to remain in thermal balance within the environment (Bowmaker & Gous, 1991).

In the case of laying hens, food intake has been shown to increase as the protein or amino acid concentration is decreased from the amount required for maximum production, and to decrease as the concentration is lowered still further (Gous et al., 1987). Bowmaker & Gous (1991) also found with broiler breeders that food intake was reduced at lysine levels below 5 g/kg feed.

Due to the time consuming nature of research on broiler breeders, few researchers have done extensive work in this area. The present experiment was designed to ascertain what effect different dietary levels of energy and protein would have on output during the total production period. The total production period was divided into three periods of 13 weeks each to establish the effects of the different dietary levels for each of the different stages of production.

The effects of dietary protein on broiler breeder production should not be investigated without considering the effect of energy. Therefore each of the four levels of protein was fed in combination with two levels of energy. In this experiment the energy and amino acid levels were higher as well as lower than the recommendation of the breeding company.

2. MATERIALS AND METHODS:

2.1 BIRDS AND MANAGEMENT:

Five hundred Hybro broiler breeder pullets at 21 weeks were purchased from a commercial breeding company at the beginning of April. During the laying period, the birds were housed in groups of 16 pullets and 2 cockerels in 32 pens, each with a floor area of 6,125 m^2. This is equivalent to 2,9 birds/m^2. Lighting was for 12½ hours per day initially, and was increased by 30 minutes per day to a total of 16 hours per day.

Separate sex feeding was applied. Round tubular feeders, suspended on a cable, was used for feeding the males. The height of the feeder was adjusted throughout the experimental period to ensure that the hens were unable to reach the feed. The females were fed in feed troughs with adjustable PVC tubes on the top which had access space of only 43 mm and ensured that the males could not consume the layer mash. Each pen also had a round drinker that provided ample water space for each bird.

2.2 TREATMENTS AND FEEDS:

No treatments were imposed during rearing. A starter diet (0 - 3 weeks) containing 11800 kJ/kg and 1,10 % lysine and a grower diet (3 - 10 weeks) containing 11400 kJ/kg and 0,80 % lysine as well as a pullet developer diet (11 - 20 weeks) containing 11100 kJ/kg and 0,60 % lysine were fed in regulated amounts, according to a commercial feeding program. The target weight of pullets at 21 weeks of age was 2300 g.

Dietary treatments commenced at 21 weeks of age and diets were formulated in such a manner as to ensure the consumption of two energy levels during the laying period (1800 kJ ME/bird/day or 2000 kJ ME/bird/day) and daily lysine intakes of 900, 1050, 1200 and 1350 mg at each energy level (Table 1) in quantities of feed allocated daily (Table 5). Diets were fed in a 2 x 4 factorial design giving a total of 8 treatments. All other amino acids were balanced in relation to lysine according to the balanced protein concept. The two energy levels were higher and lower than the recommendation of the breeders. The recommendations for the Hybro broiler breeder by the Euribrid breeding company is 1900 kJ/bird/day metabolizable energy and 1200 mg lysine/bird/day. Each treatment was replicated in four pens with 16 hens per replicate. The experiment lasted for a period of 40 weeks.

Blending the four basal feeds (Table 2) produced the 8 diets required for the experimental treatments (Table 3). In Table 4 the calculated specifications of the eight treatments is presented. All ingredients required for the feeds were purchased prior to the start of the trial to eliminate errors due to change in raw material composition. All diets were given in mash form, the allocated amount of food being presented daily at about 10:00. The feed allowances of the treatments and the breeders recommendation are shown in Table 5. The males were fed the same rations as the females.

2.3 MEASUREMENTS:

Each pen's eggs were collected, recorded and weighed daily. Every egg was marked to eliminate mistakes during handling in the hatchery. The daily number of cracks, dirty or defective eggs were also recorded. Hatchability was determined by recording the number of unhatched eggs after the incubation period and subtracting this from the total number of fertile eggs incubated. Hatchability was subsequently expressed as a percentage of the fertile eggs that was incubated after candling and subtracting this from the total number of eggs incubated. Candling was done on all the eggs when transferred from the setter on 18 days. Fertility was expressed as a percentage of the total number of eggs incubated. Hatchability and fertility were determined from 26 weeks to 61 weeks of age. The amount of chicks produced and the weight of the day old chicks was also recorded. Mortality was recorded and males that died during the trial were replaced from surplus cocks that was received on 22 weeks. The body weight of each bird was recorded at the start of the trial and every two weeks thereafter.

TABLE 1: **The experimental design.**

Treatment	Daily Intake	
	Energy (kJ ME)	**Protein (mg Lysine)**
1	2000	900
2	2000	1050
3	2000	1200
4	2000	1350
5	1800	900
6	1800	1050
7	1800	1200
8	1800	1350
Breeder Standard	1900	1200

TABLE 2: **Composition of the basal diets used during the laying period.**

Composition (%)	Diet			
	1	4	5	8
Limestone	8,375	8,296	9,071	9,012
Maize meal	80,807	63,969	78,132	58,420
Calcium Phosphate	0,979	0,44	0,911	0,663
Pollard	0,018			
Synthetic Lysine	0,11	0,055		0,102
Synthetic Methionine		0,005		0,036
Oil		2,809		4,500
Salt	0,201	0,058	0,098	0,054
Sunflower	4,386	14,244	3,148	17,087
Vitamin Mineral Mix	0,125	0,125	0,125	0,125
Fishmeal	5,000	10,000	8,516	10,000

TABLE 3: **Proportions (%) of the four basal feeds used to produce the eight treatments in the experiment.**

Treatment	Basal Diet			
	1	4	5	8
1	100			
2	66,6	33,3		
3	33,3	66,6		
4		100		
5			100	
6			66,6	33,3
7			33,3	66,6
8				100

TABLE 4: **The calculated specifications of the experimental diets used in the laying period.**

	Treatment / Diet							
	1	2	3	4	5	6	7	8
Daily allowance								
Metabolizable Energy (kJ/bird)	2000	2000	2000	2000	1800	1800	1800	1800
Lysine (mg/bird)	900	1050	1200	1350	900	1050	1200	1350
Composition (%)								
Arginine	0,744	0,894	1,046	1,198	0,812	0,965	1,119	1,274
Calcium	3,35	3,347	3,347	3,35	3,66	3,656	3,656	3,66
Fat	2,763	2,669	2,578	2,49	2,734	2,606	2,481	2,358
Glycine + Serine	1,476	1,784	2,093	2,404	1,894	2,083	2,274	2,467
Histidine	0,326	0,375	0,424	0,473	0,356	0,401	0,447	0,493
Isoleucine	0,501	0,576	0,652	0,729	0,564	0,627	0,69	0,754
Leucine	1,534	1,618	1,704	1,792	1,639	1,686	1,735	1,785
Linoleic acid	1,576	2,012	2,449	2,889	1,517	2,255	2,994	3,737
Lysine	0,563	0,656	0,75	0,844	0,627	0,718	0,81	0,903
Metabolizable Energy (MJ/kg)	12,5	12,488	12,488	12,5	12,5	12,488	12,49	12,5
Methionine	0,268	0,318	0,368	0,419	0,322	0,368	0,414	0,46
Methionine + Cystine	0,496	0,566	,0637	0,709	0,553	0,621	0,69	0,759
Sodium	0,158	0,158	0,158	0,158	0,158	0,158	0,158	0,158
Phosphorus	0,4	0,399	0,4	0,4	0,45	0,45	0,45	0,45
Phenylalanine + Tyrosine	1,014	1,139	1,265	1,392	1,11	1,216	1,323	1,432
Protein	12,403	14,303	16,215	18,146	13,918	15,547	17,191	18,853
Threonine	0,486	0,56	0,634	0,709	0,557	0,614	0,672	0,731
Tryptophan	0,126	0,153	0,18	0,207	0,141	0,167	0,193	0,219
Fibre	1,993	2,15	2,308	2,469	1,857	2,098	2,34	2,585
Moisture	10,617	10,511	10,416	10,331	10,583	10,432	10,291	10,161
Protein (g/day)	19,8	22,88	25,9	29,02	20,00	22,3	24,6	27

TABLE 5: **The daily feed allowance of the treatments and breeders recommendation.**

Age in weeks	Breeders Recommendation		Treatment / Diet (1 – 4)		Treatment / Diet (5 – 8)	
	Females (g)	Males (g)	Females (g)	Males (g)	Females (g)	Males (g)
21	110	110	110	110	110	110
22	120	120	130	120	117	120
23	130	125	130	120	117	120
24	140	130	140	130	126	130
25	150	135	140	130	126	130
26	160	135	140	130	126	130
27	165	135	150	135	135	135
28	165	135	160	135	144	135
29	165	135	160	135	144	135
30	165	135	160	135	144	135
31	165	135	160	135	144	135
32	165	135	165	135	149	135
33	165	135	165	135	149	135
34	165	135	160	135	144	135
35	164	135	160	135	144	135
40	159	135	160	135	144	135
50	150	130	151	135	136	135
60	150	130	151	135	136	135

3. RESULTS AND DISCUSSION

Since the requirements of birds for energy and protein were likely to change during lay, the 39 weeks experimental period was divided into three phases, 23 to 35 weeks, 36 to 48 weeks and 49 to 61 weeks of age in order to evaluate the responses of hens at different ages. The results are illustrated in Fig. 3 to 39. The mean response and its statistical significance to amino acids at different energy levels is shown in Tables 7 to 15.

3.1 HEN DAY PRODUCTION:

Results are summarized in Table 6 and graphically illustrated in Fig. 1 and Fig. 2 for the high and the low energy diets respectively. It appears as if the higher energy level (Fig. 1) had a beneficial effect during the period of peak production and birds receiving the lower energy diets (Fig. 2), performing better in the later stages of production.

A statistical analyses of the data (Table 7) revealed a significant effect of energy level on hen day egg production for only the third period of production (49 - 61 weeks). There were no significant interactions between energy level and protein intake and it was thus statistically justifiable to make conclusions on main effects (see addendum 1 - 4). The apparent beneficial effect of the high energy intake at a low protein level, as depicted in Fig. 3, was not significant (no significant interaction as shown in the analyses of variance in Table 7). Breeders on the high energy diet had indeed a lower egg production rate during period 3 (49 - 61 weeks of age) which was independent of protein intake (Fig. 5).

Over the entire period of 39 weeks, no statistically significant differences in hen day egg production existed (Table 7) between the different dietary treatments. These results are shown in Fig. 7. A tendency existed for egg production to increase with increasing amounts of protein, regardless of energy level. However intake levels of 1200 mg lysine per day showed no tendency to increase egg production above that on 1050 mg/day. There was even a tendency for a decline in egg production towards 1350 mg/day/hen. On the other hand on the lower energy level (1800 vs 2000 kJ/day) the tendency persisted to increase production with increasing levels of protein to a level of 1200 mg lysine per day and declined at a level of 1350 mg/day.

From the results of the present experiment it was not possible to make an unambiguous statement that the lower energy level with lysine intakes of 1200 mg/day was more beneficial to ensure a high level of production than a higher energy level of 2000 kJ/day.

TABLE 6: **Percentage Hen Day Production of the females during the experimental period.**

Treatment									
Age Weeks	Breeder Standard (%)	A 900 mg Lysine	B 1050 mg Lysine	C 1200 mg Lysine	D 1350 mg Lysine	E 900 mg Lysine	F 1050 mg Lysine	G 1200 mg Lysine	H 1350 mg Lysine
		2000 kJ ME/bird/day				1800 kJ ME/bird/day			
21	0	0	0	0	0	0	0	0	0
23	1	0,69	2,04	0,92	0	0,95	0,23	0	0,46
25	24	20,05	24,19	23,19	19,46	18,10	19,29	19,5	18,89
27	62	62,9	62,38	67,49	65,11	63,33	71,67	64,85	69,58
29	80	76,11	73,81	80,79	75,55	71,19	75,54	80,65	77,88
31	81	77,52	80,71	81,40	75,55	69,98	77,59	81,9	73,33
33	79	80,48	82,38	81,67	81,87	80,87	79,80	82,62	83,67
35	77	80,15	75,98	81,40	82,14	82,32	77,34	75,71	78,57
37	75	78,82	79,52	76,28	80,77	81,11	76,19	75,95	76,02
39	73	70,94	75,48	72,77	81,32	72,64	73,47	77,38	73,47
41	71	67,98	70,2	71,69	72,53	64,16	67,35	71,19	71,17
43	69	64,91	65,66	69	63,74	61,98	64,29	67,86	65,38
45	67	64,41	61,65	65,5	64,01	63,79	63,37	68,33	65,11
47	65	62,16	65,66	64,96	69,23	60,15	62,24	67,14	62,18
49	63	59,95	56,14	60,38	58,79	60,65	50,00	62,62	56,86
51	61	56,62	55,39	62,8	57,97	63,52	60,20	65,24	63,56
53	59	54,5	50,26	54,99	50	55,87	58,16	55,95	59,52
55	57	56,87	54,08	58,76	49,18	60,05	59,18	60,05	69,64
57	55	56,06	52,04	55,22	47,34	52,65	64,29	56,65	61,61
59	53	44,47	53,51	49,02	43,70	43,94	53,83	49,01	49,70
61	51	48,29	57,94	41,46	52,48	44,74	50,00	51,97	43,45

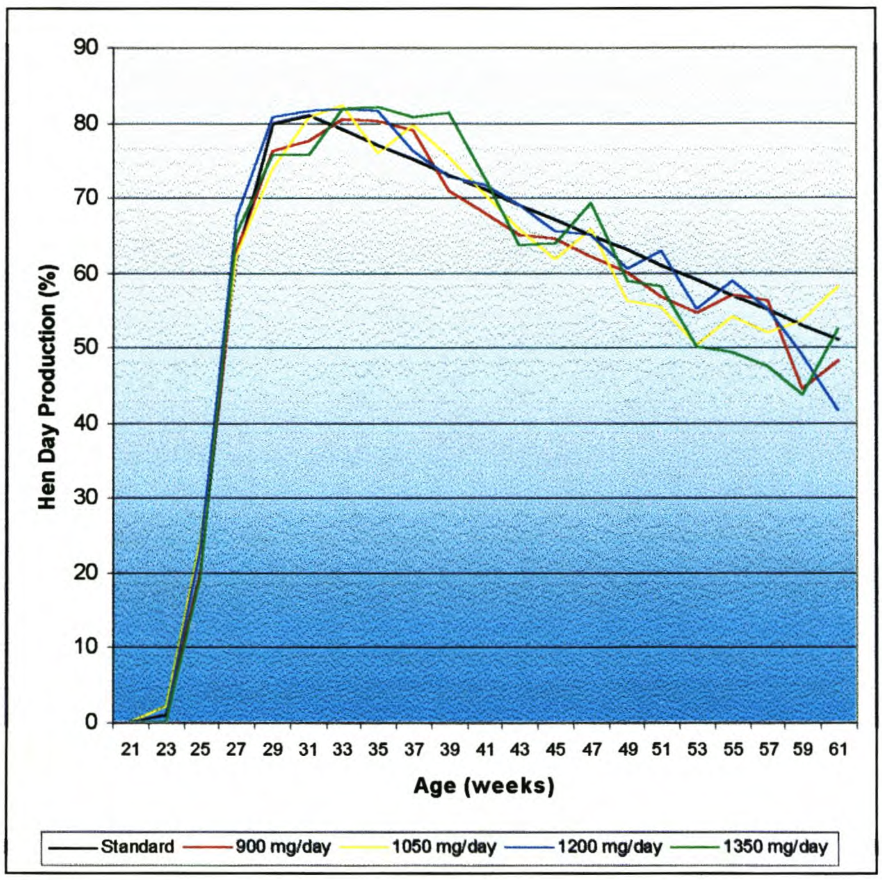


FIGURE 1 : The Hen Day Production of the females on the high energy diets (2000 kJ/day).

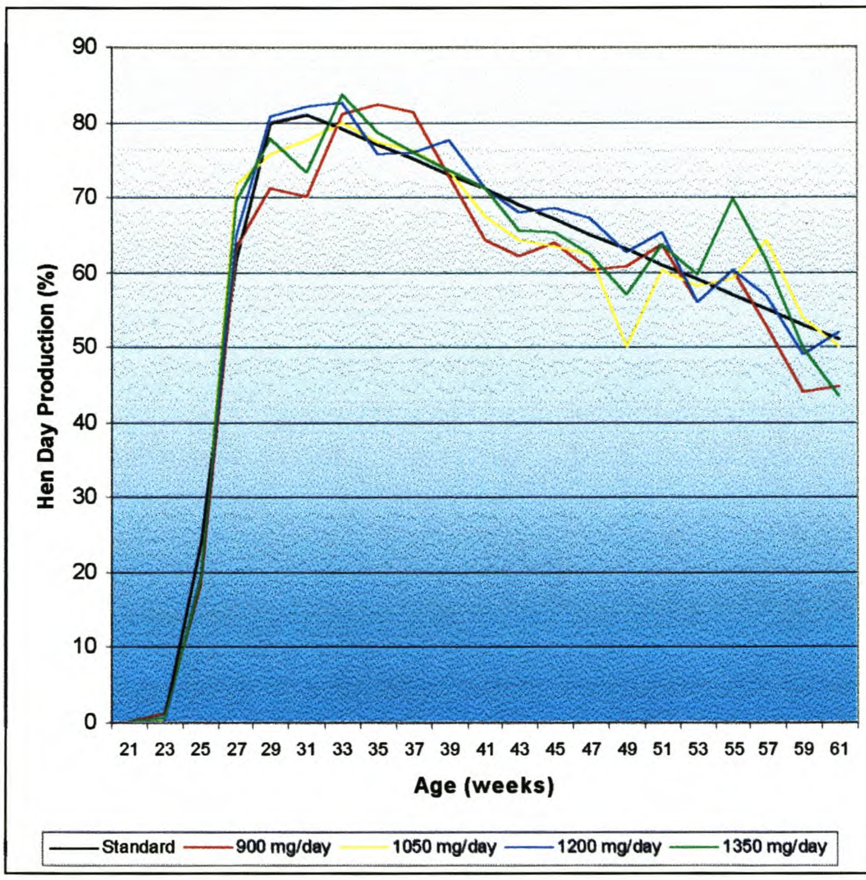


FIGURE 2 : The Hen Day Production of the females on the low energy diets (1800 kJ/day).

TABLE 7: **The effect of different combinations of energy and lysine on Hen Day Production of broiler breeder females during different periods of production.**

TABLE 7: **The effect of different combinations of energy and lysine on Hen Day Production of broiler breeder females during different periods of production.**
(see addendum 1 - 4 for statistical analysis)

Daily Intake		**Age (Weeks)**			
Energy (k J ME / Bird)	**Lysine (mg / Bird)**	**23 - 35**	**36 - 48**	**49 - 61**	**23 - 61**
2000	900	57,85	67,75	53,37	59,86
	1050	58,83	70,10	54,20	60,99
	1200	59,07	70,69	53,86	61,23
	1350	56,81	71,75	50,26	59,63
1800	900	55,39	68,86	53,83	59,36
	1050	57,37	69,18	55,05	60,51
	1200	59,46	71,70	56,90	62,60
	1350	57,46	68,52	57,66	61,13
Standard Deviation		**±3,130**	**±2,984**	**±4,060**	**±2,132**
Statistical Significance					
Main Effects					
Energy (E)		NS	NS	* *	NS
Protein (P)		NS	NS	NS	NS
Interaction: E x P		NS	NS	NS	NS
NS : Not significant					
**** : P <0,05**					
***** : P < 0,01**					

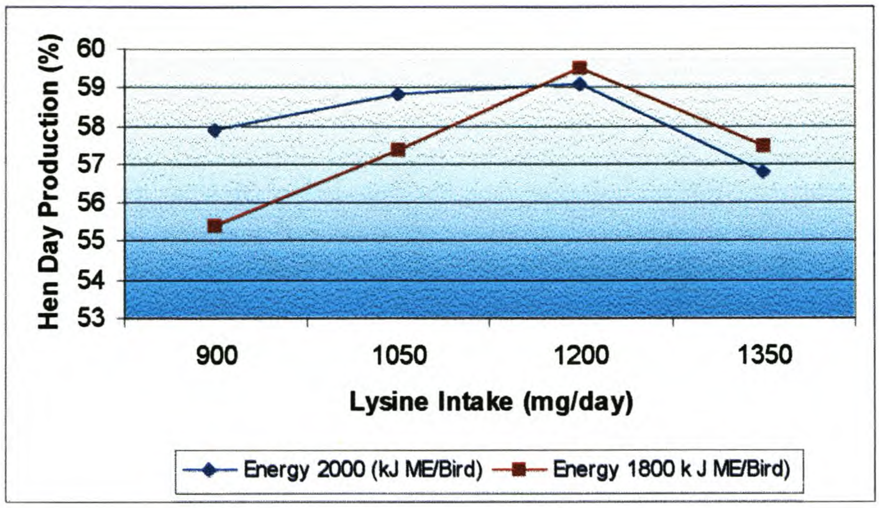


FIGURE 3: Response in Hen Day Production to amino acid intake in period 1 (week 23 – 35) fed diets of different energy content.

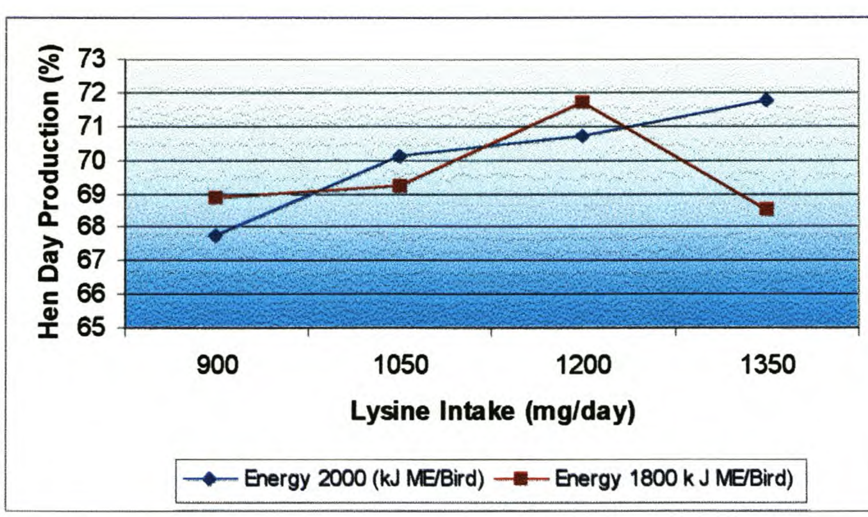


FIGURE 4: Response in Hen Day Production to amino acid intake in period 2 (week 36 - 48) fed diets of different energy content.

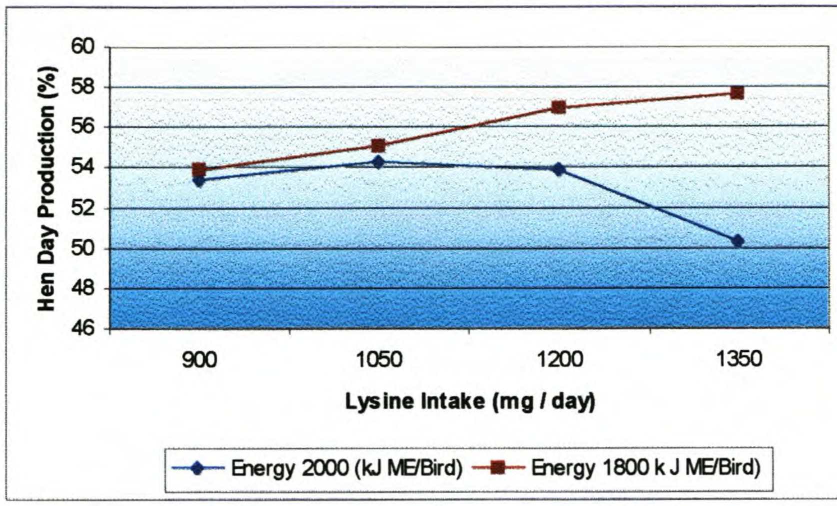


FIGURE 5: Response in Hen Day Production to amino acid intake in period 3 (week 49 - 61) fed diets of different energy content.

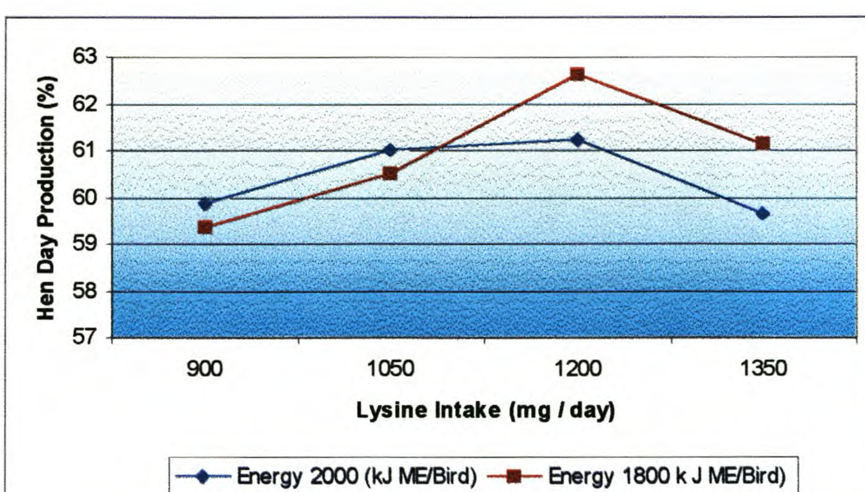


FIGURE 6: Response in Hen Day Production to amino acid intake in the total period (week 23 - 61) fed diets of different energy content.

This is supported by work done by McDaniel (1983). Robbins et al., (1988) found that birds fed ad libitum during the pullet layer transition (24 - 32 weeks) produced more eggs, but this effect was not significant. Wilson & Harms (1986) also indicated a beneficial effect of birds receiving ad libitum feeding, resulting in higher energy intakes, on egg production in the earlier period (29 - 40 weeks) of production. Egg production however decreased rapidly after 40 weeks of age in the ad libitum fed birds.

Numerous reports have appeared in the literature on the effect of energy intake on production responses of breeders. Spratt (1987) also indicated a positive correlation between energy intake and egg production with the highest energy intakes regarded as 1883 kJ/day/bird. Despite coming into production sooner, ad libitum fed broiler breeders lay fewer eggs than do restricted hens (Robbins et al., 1986; Katanbaf et al., 1989a; Robinson et al., 1991b; O'Sullivan et al., 1991; Yu et al., 1992). Ad libitum fed and restricted hens lay eggs in a similar number of sequences, however the prime sequence was shorter in ad libitum fed hens (Robinson et al., 1991). Ad libitum fed broiler breeder hens do not adhere to the models of the ovulatory cycle (Etches, 1990) as strictly as do egg type hens. Classic studies conducted by Jaap & Muir (1968) and Robinson et al., (1993) indicated a condition known as erratic oviposition and defective egg syndrome (EODES). The EODES – affected hens laid a high incidence of multiple-yolked eggs and frequently lay more than one egg per day (Jaap & Muir, 1968; Katanbaf et al., 1989; Yu et al., 1992). Such hens lay in an erratic nature throughout the day and night. Yu et al., (1992) observed that in the first few weeks of lay, hens that were ad libitum fed during both the rearing and breeding periods laid 40,8 % of their eggs outside of the normal period of laying (first 10 hours after the dawn signal). This observation indicates that the hens are either ovulating throughout the day and night, or the time spent in the shell gland is of a variable and erratic nature, or both. Ad libitum fed broiler breeders have more large follicles than do restricted hens (Yu et al., 1992). Under conditions of feed restriction broiler breeders have similar numbers of large yolk follicles as do egg type hens (Williams & Sharp, 1978). The increased number of follicles seen in response to ad libitum feeding during the laying period has been shown to be evident after a few days of over consumption (Robinson et al., 1993). These follicles are included in the hierarchy in the form of double or triple hierarchies (Hocking et al., 1987, 1989; Robinson et al., 1991; Yu et al., 1992).

Ad libitum feed consumption also affects the pool of small follicles. At the time of the first oviposition, ad libitum fed broiler breeders have about twice as many small follicles between 1 and 8 mm in diameter as do egg type hens (Hocking et al., 1987). It was stressed by Robinson et al., (1993c) that increased follicle development, seen in response to overfeeding, does not result in a significant increase in egg production. In broiler breeders, extra follicles would appear to be an undesirable trait, as the excess follicles disrupt normal ovarian function (Yu et al., 1992). It has been shown that the major variable determining the incidence of multiple ovulations is bodyweight at maturity. However the level of feeding between photostimulation and maturity also has a significant effect (Fisher, 1998). To investigate this, birds were fed either a " slow" (average 115,3 g/day) feed schedule in week 20 through 25 or a "fast" (average 132,5 g/day) feed schedule. Egg production to 64 weeks on the "slow" schedule was 11 eggs higher than the "fast" schedule (200,3 eggs versus 189,4 eggs).

Egg production is also reduced in ad libitum fed broiler breeder hens due to ovarian regression. Yu et al., (1992) reported that at 62 weeks of age, the incidence of regression was 6,3 % for hens that had been fed according to industry standards of feed restriction, whereas 28,6 - 40 % of hens that had been ad libitum fed during rearing or breeding, or both, exhibited ovarian regression.

Regulation of food intake during the breeding period has to be applied carefully because of the need to maintain egg output. Over restriction can decrease egg production (Pym & Dillon, 1974; Chaney & Fuller, 1975; Blair et al., 1976). However, some reduction in energy and protein allowance in the later part of the laying cycle may give improvements in performance when compared with feeding ad libitum (Blair et al., 1976).

Lilburn & Myers-Miller (1990a) observed that aggressive feeding for maximal early egg production may not necessarily result in excessively heavy hens at peak egg production. This observation is in contrast to a report by Leeson & Summers (1983) in which hens that were induced to lay via accelerated feeding did not continue to lay well and were significantly fatter after peak production. Thus, there is a delicate balance between feeding for the onset of production and obtaining a maximal number of eggs per hen over the entire laying period.

In the present experiment, hen day production responded positively to increasing levels of amino acids up to an intake level of 1200 mg/day/hen on the lower energy level of 1800 kJ/day (Fig. 4 - 6). This amount is substantially more than the value of 765 mg/bird/day reported by the National Research Council (NRC, 1984). According to Bowmaker & Gous (1991) levels of 918 - 1272 mg lysine and 335 - 524 mg methionine/bird/day resulted in the best performance, especially in terms of egg production, suggesting that the lysine needs were probably underestimated by the NRC. In the light of the work by Bowmaker & Gous the present level was probably sufficient to support the birds to their fullest potential for egg production.

According to Lopez & Leeson (1995) there are no benefits in feeding broiler breeder hens after they are 45 weeks of age more than 21 grams of crude protein per hen per day. Caged broiler breeder hens were fed protein to provide levels of 21, 24, 27 or 30 grams of crude protein per hen per day over a 10 week period. The diets contained similar levels of methionine and lysine. At the highest level of daily protein intake, egg production was reduced. The current results show comparisons with these of Lopez & Leeson (1995).

Production was also depressed at the higher levels of protein intake. According to the results of the hen day production over the total period (23 - 61 weeks), it appears as if a level of protein above 25 g/day/bird has a negative effect on production, although not significant. Spratt (1987) found that high protein (25 g/day) intakes reduced egg production.

In the present work the positive response seems to reach a plateau at the highest amino acid level. The highest production was found at the lower energy level (1800 kJ ME) and 1200 mg lysine intake per day (Fig. 6).

3.2 EGG WEIGHTS:

Energy and protein intake had highly significant (P < 0,01) effects on the average egg weight (g/egg) in the total production period (Table 8). No significant interaction was found between energy and protein levels and discussion of main effects is therefore justified. The beneficial (P < 0.01) effect of protein was consistent during all three periods of production (Fig. 7 - 10) and there was a tendency for egg weight to increase with increasing protein intake. However, differences were only statistically significant between the highest (1350 mg lysine) levels of intake and the other three amino acid level intakes (see Addendum 5 - 8).

Birds on the high energy intakes produced significantly larger eggs than birds on the low energy intakes. This was true for periods 1 and 3, but differences for period 2 were not significant.

A number of factors have been reported to affect the egg size of broiler breeders. The most important being linoleic acid, protein and certain amino acids (Lopez & Leeson, 1994).

The maximum response to linoleic acid intake has not been well established for broiler breeder hens, although Brake et al., (1989) found that supplementation of 24 g/kg of linoleic acid diet fed to broiler breeders from 22 to 64 weeks of age had some effect on egg weight. Much of the controversy surrounding the relationship between egg weight and dietary fat is due to the confounding effect of the energy contribution of fat. In the present study, the linoleic acid levels increased as the protein levels increased (Table 4). The calculated intakes of linoleic acid was lower on the four higher energy diets (15,8 g, 20,1 g, 24,5 g and 28,9 g) than on the comparative diets with the four lower energy (15,2 g, 22,6 g, 29,9 g and 37,4 g) content. It was only on the diets with the lowest amino acid level where the linoleic acid intake was higher on the high energy diets. This could indicate that the significant effect of energy on egg weight was due to the energy contribution of the diet and not the level of linoleic acid. It could be argued that the levels of linoleic acid was not high enough to effect egg size.

The effects of dietary protein and amino acids on egg weight have been thoroughly investigated in broiler breeders (Pearson & Herron, 1980, 1981, 1982a; Spratt & Leeson, 1987). The variability in reported data can be partly explained by the fact that requirements for egg production and egg weight are sometimes difficult to separate. Waldroup et al., (1976) suggested the protein requirement for both egg production and egg weight to be comparable for broiler breeder hens.

TABLE 8: **The effect of different combinations of energy and lysine on Average Egg Weight (g) of broiler breeders females during different period of production.** (see addendum 5 - 8 for statistical analysis)

Daily Intake		**Age (Weeks)**			
Energy (kJ ME/Bird)	**Lysine (mg/Bird)**	**23 - 35**	**36 - 48**	**49 - 61**	**23 - 61**
2000	900	57,11	64,52	68,86	63,12
	1050	57,60	64,53	69,18	63,50
	1200	57,61	64,46	68,62	63,32
	1350	59,55	66,20	69,98	65,07
1800	900	54,31	62,70	67,38	61,35
	1050	56,47	63,55	68,25	62,63
	1200	57,72	63,33	68,26	62,65
	1350	58,48	66,48	69,99	64,60
Standard Deviation		**±1,241**	**±1,387**	**±0,819**	**±0,913**
Statistical Significance					
Energy (E)		***	NS	**	***
Protein (P)		***	***	***	***
Interaction: E x P		NS	NS	NS	NS

NS : Not significant

**** : P < 0,05**

***** : P < 0,01**

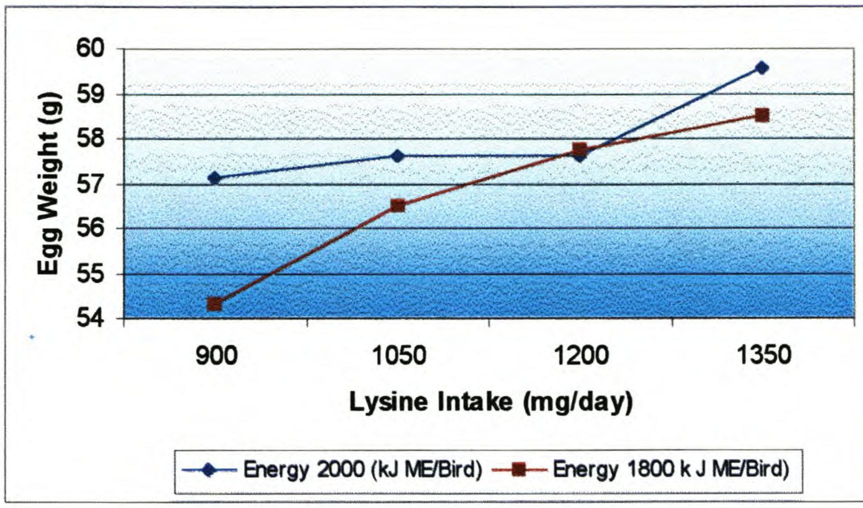


FIGURE 7: Response in Average Egg Weight to amino acid intake in period 1 (week 23 - 35) fed diets of different energy content.

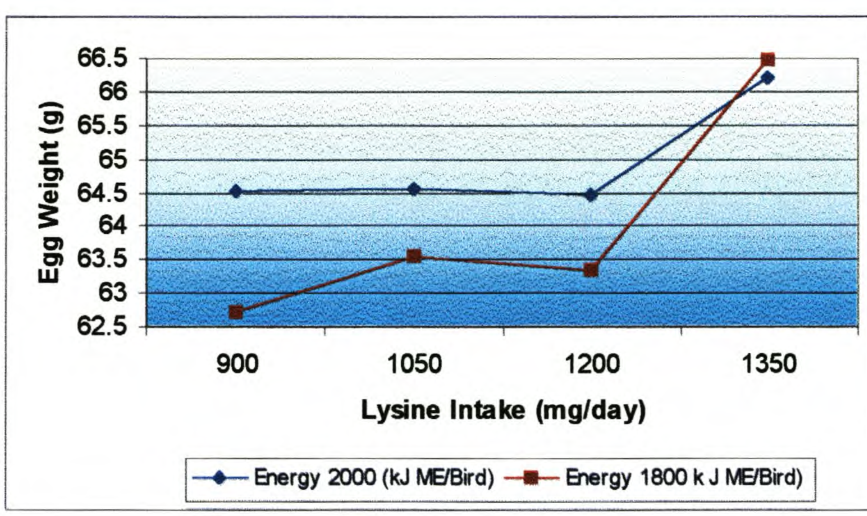


FIGURE 8: Response in Average Egg Weight to amino acid intake in period 2 (week 36 - 48) fed diets of different energy content.

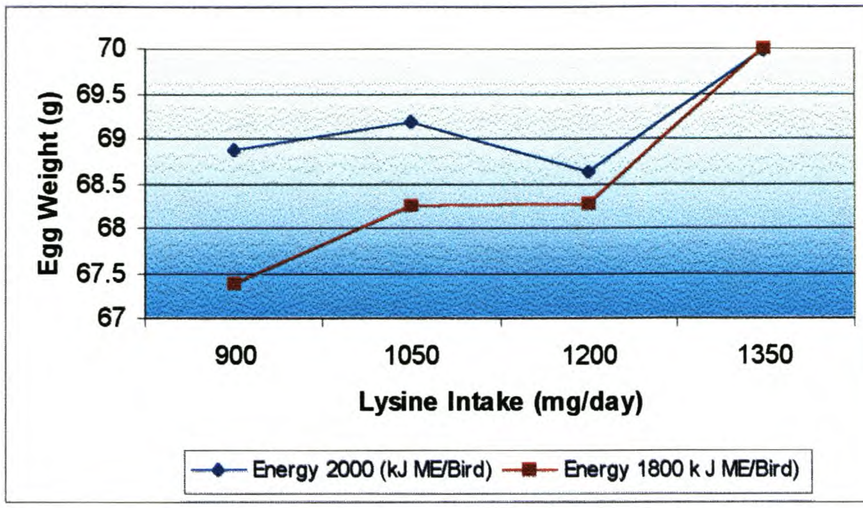


FIGURE 9: Response in Average Egg Weight to amino acid intake in period 3 (week 49 - 61) fed diets of different energy content.

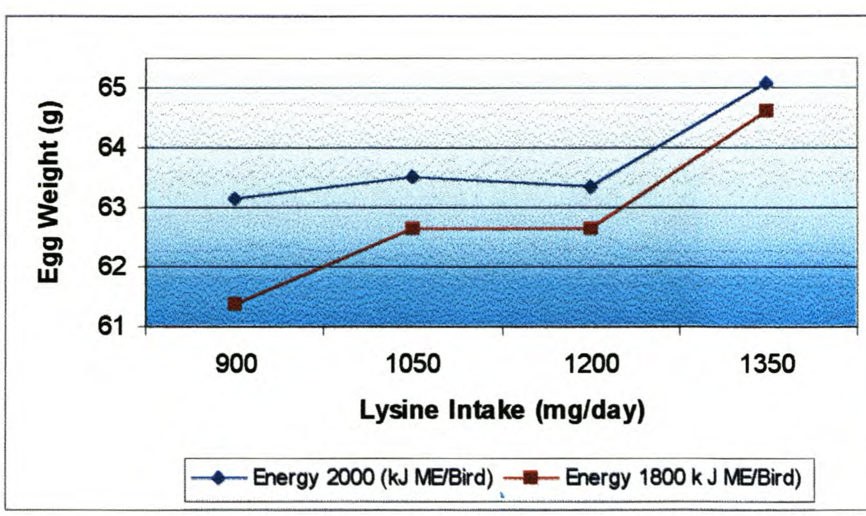


FIGURE 10: Response in Average Egg Weight to amino acid intake in the total period (week 23 - 61) fed diets of different energy content.

Other workers (Spratt & Leeson, 1987) report protein requirements of 19 g/bird/day to achieve optimum egg production and 25 g/bird/day to achieve maximum egg weight. These observations are in agreement with the findings of other workers (Wilson & Harms, 1986; Pearson & Herron, 1982 and McDaniel et al., 1981b). This is also in agreement with the present study where egg production reached a plateau at 1050 - 1200 mg/day/bird lysine intake. Egg weight however still increased at the highest lysine intake (1350 mg/day/bird).

Harms & Ivy (1992) suggested the daily lysine requirements in a balanced protein for egg production, egg weight and egg output to be 824, 806 and 819 mg, respectively, when protein intake is higher than 18,6 g/day.

Bowmaker & Gous (1991) showed that small increments in intake of amino acids (lysine and methionine) that were close to the optimum resulted in equal proportional response in rate of lay and egg weight, but that when there were severe deficiencies of lysine and methionine, egg production was reduced to a greater extent than egg weight was. In cases of marginal deficiency, only a reduction in egg weight is observed. These workers suggested that the effect of a reduction in amino acid supply on the rate of lay and on egg weight is the same for broiler breeder hens as it is for laying pullets. Egg weight appears to reach a minimum size of 0,8 of the maximum below which it does not drop as the amino acid supply is reduced still further.

3.3 EGG MASS OUTPUT:

The response in egg mass output on the experimental diets over the total period (week 23 - 61) indicate increasing levels of protein had a significant ($P < 0,05$) effect on the egg mass output (Fig. 14). There was no consistent protein effect on egg mass during the individual periods, being only significant in the second period (Table 9). However over the entire period the low protein level was significantly lower than on the highest level. Egg mass output on the higher amino acid levels (1050, 1200 and 1350 mg/day) however did not differ from each other (Analyses of variance - see addendum 9 - 12).

The response of egg mass output is an example of a change in the requirement of broiler breeders during the laying period. Pearson & Herron (1980) also found an apparent lack of response of broiler breeders to reductions in protein intake in the last third of production (week 52 - 64). This could be because requirements of broiler breeders for protein in the later stages of the laying cycle are less than current feeding standards indicate.

With regard to energy the birds on the high energy diet produced a significant higher egg mass per hen during period 1 (Fig. 11). This was not true for any of the other periods or when results over the entire period (23 - 61 weeks) were analyzed.

TABLE 9: **The effect of different combinations of energy and lysine on Egg Mass Output (g/day) of broiler breeder females during different periods of production** (see addendum 9 - 12 for statistical analysis)

Daily Intake		Age (Weeks)			
Energy (kJ ME/Bird)	**Lysine (mg/Bird)**	**23 - 35**	**36 - 48**	**49 - 61**	**23 - 61**
2000	900	33,04	43,72	36,83	37,85
	1050	33,88	45,23	37,50	38,73
	1200	34,04	45,55	36,96	38,77
	1350	33,85	47,45	35,40	38,79
1800	900	30,08	43,18	35,81	36,29
	1050	32,31	43,96	37,56	37,87
	1200	33,72	45,42	38,86	39,29
	1350	33,60	45,53	40,34	39,49
Standard Deviation		**±1,735**	**±1,896**	**±2,684**	**±1,341**
Statistical Significance					
Energy (E)		**	NS	NS	NS
Protein (P)		NS	**	NS	**
Interaction: E x P		NS	NS	NS	NS
NS : Not significant					
**** : P < 0,05**					
***** : P < 0,01**					

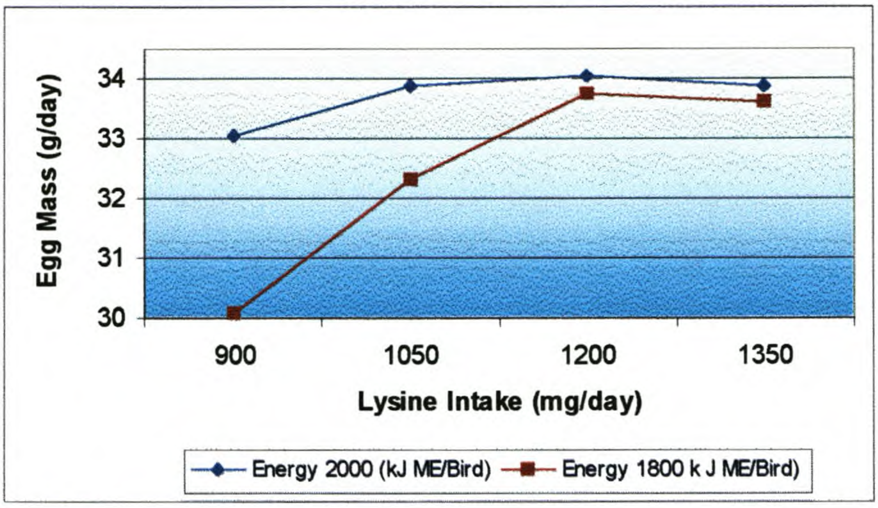


FIGURE 11: Response in Egg Mass Output to amino acid intake in period 1 (week 23 - 35) fed diets of different energy content.

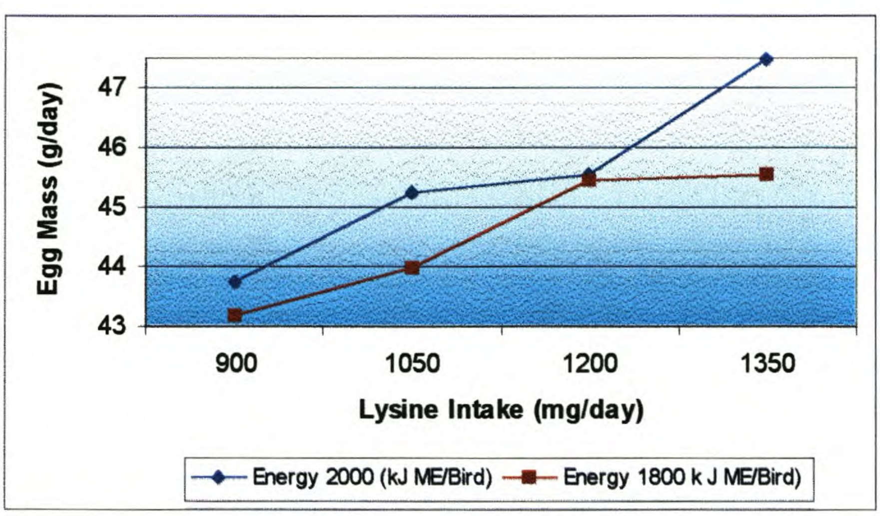


FIGURE 12: Response in Egg Mass Output to amino acid intake in period 2 (week 36 - 48) fed diets of different energy content.

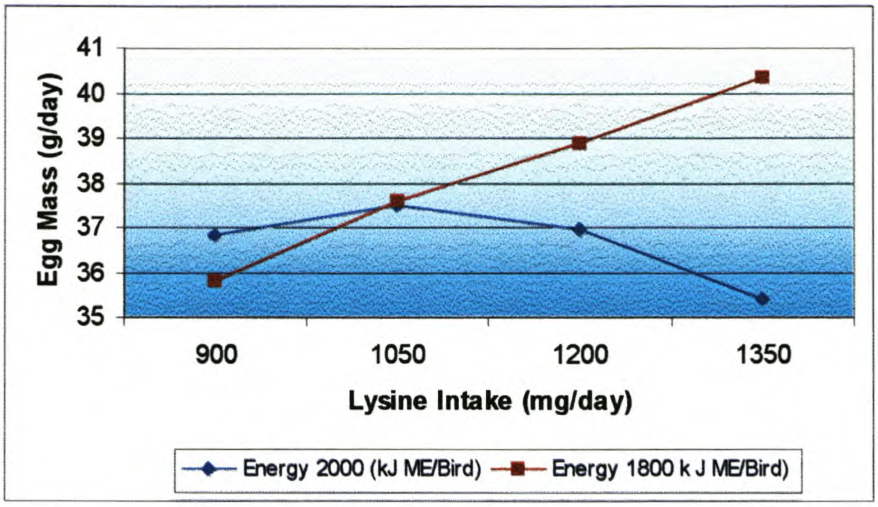


FIGURE 13: Response in Egg Mass Output to amino acid intake in period 3 (week 49 - 61) fed diets of different energy content.

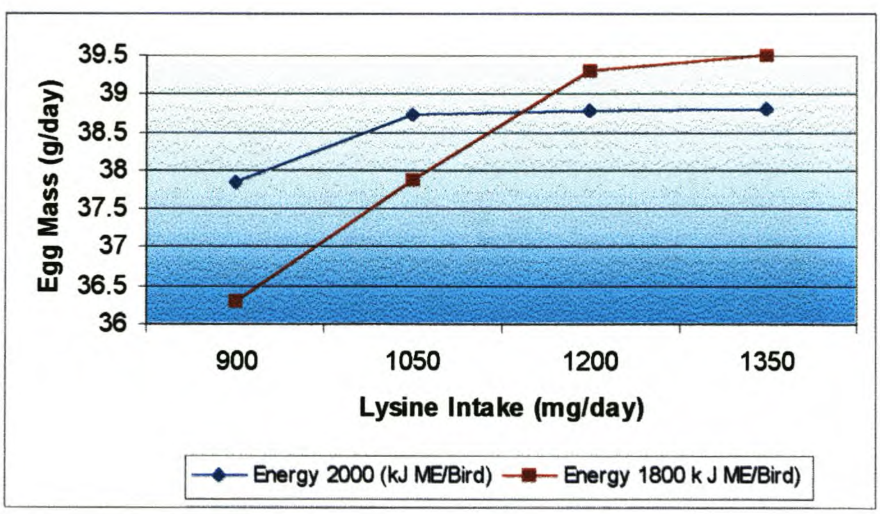


FIGURE 14: Response in Egg Mass Output to amino acid intake in the total period (week 23 - 61) fed diets of different energy content.

3.4 FERTILITY:

Successful hatching of an egg depends upon a fertile egg having adequate nutrients and environmental conditions, such that the embryo can develop into a viable chick.

No significant effect (Table 10) was noticed during this experiment to indicate that dietary protein or energy has any effect on fertility (Fig. 15 - 18). The highest fertility was, however, noticed at an amino acid level of 1200 mg lysine per day at both energy levels. The fertility declined at the highest amino acid level and this effect was more profound at the higher energy level. In the present experiment the weight of males was maintained according to the breeder's standards. There was also no indication that fertility was influenced when the weights of the males was significantly lower in the treatment that received the lowest protein and energy intake (1800 kJ and 900 mg lysine). Small differences in body weight do not influence fertility or hatchability to a great extent according to a few authors (Wilson & Harms, 1986; Fattori et al., 1991; Robinson & Robinson, 1991). Fertility of broiler breeders is affected primarily by male performance (Wilson et al., 1979, 1987; Hocking, 1989 and Hocking & Duff, 1989).

The negative effect of high protein levels on fertility has been shown. Authors attributed this to the beneficial effects of low protein feeds on body weight and thus mating activity (Fisher, 1998). Lopez & Leeson (1995) also indicated that protein level of the diet of breeder hens had a significant effect on fertility. The methionine and lysine levels in their work were kept constant, as was energy level, and only diet crude protein was varied (10, 12, 14 and 16 %). All roosters were fed a separate male diet at 12 % CP to ensure the results was due to the female effect. The best fertility was achieved with 10 and 12 % protein diets.

The nutrient requirements of the broiler breeder males are lower than those of the broiler breeder hen. According to Bootwalla & Miles (1990), adult breeder males require between 8,8 and 15,6 g of crude protein per day. Diets low in crude protein (8 to 12 %) can sustain semen production in adult breeder males (Wilson et al., 1987a & b; Revington et al., 1991) and may control body weight gain when fed on a restricted basis.

In naturally mating flocks, there is a normal decline in fertility with age (Hocking, 1990a), and most of this decline is attributed to males. The influence of obesity on reproductive function in broiler breeder males seems to be of a physical or behavioral rather than a physiological nature (Hocking, 1990b). Excessive weight gain during the rearing period and the resulting heavy body weight has a negative impact on breeders male fertility (Ingram & Wilson, 1987). As body weight increases, males are more susceptible to mechanical disorders involving feet and leg problems, and such problems interfere with normal mating activity (Burke & Mauldin, 1985; Hocking & Duff, 1989). It has been suggested that very large males may experience anatomical problems in achieving cloacal contact due to their large body size (Soller et al., 1965; Hocking & Duff, 1989). Brake (1996) also found a general decline in fertility of the male around 40 weeks of age, irrespective of the male feeding program. This decrease coincides with an increase in male body weight.

Studies were done which was related to the correlation of semen characteristics and fecundity to body weight. Siegel (1963) reported that after four generations of selecting for increased weight at eight weeks the following responses were noted in relation to semen quality: 1. Motility of spermatozoa was negatively correlated with the selected trait; 2. Semen volume was positively related to the selected trait; and 3. The concentration of spermatozoa was not related to the selected trait. Edens et. al., (1970) found that by the eleventh generation there was a significantly reduced endogenous sperm respiration in the high weight line. They later reported a significant increase in the percentage of dead and abnormal sperm in the high weight line (Edens et al., 1973). A negative correlation between rate of gain and sperm motility was also observed by Soller et al., (1965).

Fontana et al., (1990) concluded that the weights of the testes was more closely associated with body size than with the level of protein. This outcome agrees with the findings of Wilson et al., (1987a) who reported no difference in the weights of

TABLE 10: **The effect of different combinations of energy and lysine on Fertility (%) of broiler breeder females during different periods of production**

TABLE 10: **The effect of different combinations of energy and lysine on Fertility (%) of broiler breeder females during different periods of production**

(see addendum 13 - 16 for statistical analysis)

Daily Intake		**Age (Weeks)**			
Energy (kJ ME/Bird)	**Lysine (mg/Bird)**	**23 - 35**	**36 - 48**	**49 - 61**	**23 - 61**
2000	900	93,12	93,81	85,31	91,11
	1050	91,69	93,70	88,96	91,69
	1200	91,29	94,88	89,54	92,23
	1350	90,03	92,07	87,94	90,28
1800	900	91,02	94,27	89,59	91,91
	1050	90,92	93,13	84,58	89,81
	1200	92,73	95,19	88,85	92,52
	1350	93,47	94,83	87,94	92,37
Standard Deviation		**±2,233**	**±1,404**	**±4,512**	**±1,794**
Statistical Significance					
Energy (E)		NS	NS	NS	NS
Protein (P)		NS	NS	NS	NS
Interaction: E x P		NS	NS	NS	NS
NS : Not significant **** : P < 0,05** ***** : P < 0,01**					

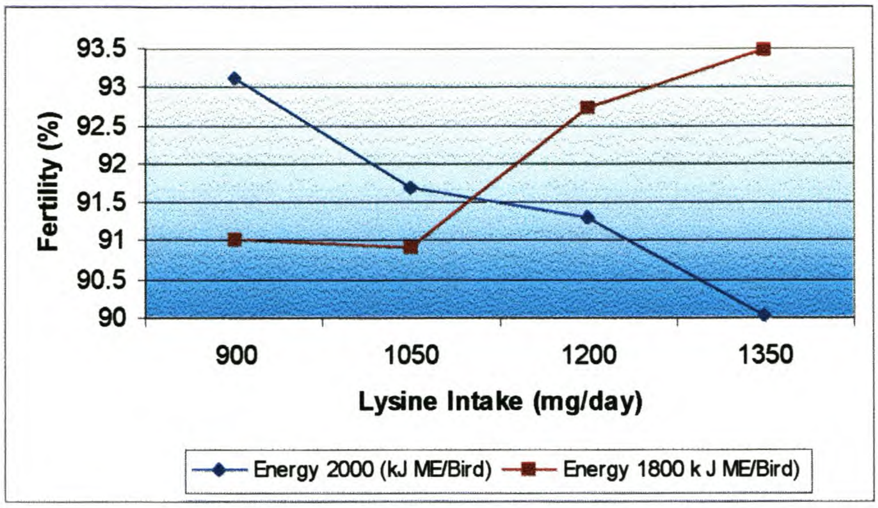


FIGURE 15: Response in Fertility to amino acid intake in period 1 (week 23 - 35) fed diets of different energy content.

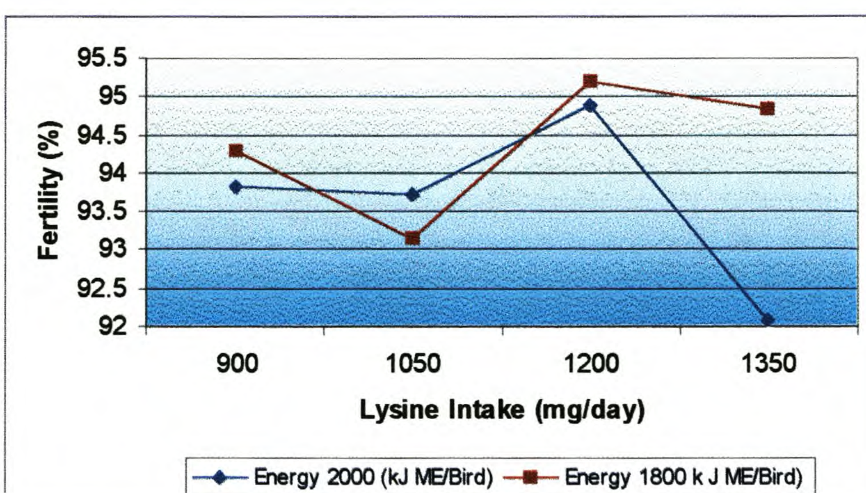


FIGURE 16: Response in Fertility to amino acid intake in period 2 (week 36 - 48) fed diets of different energy content.

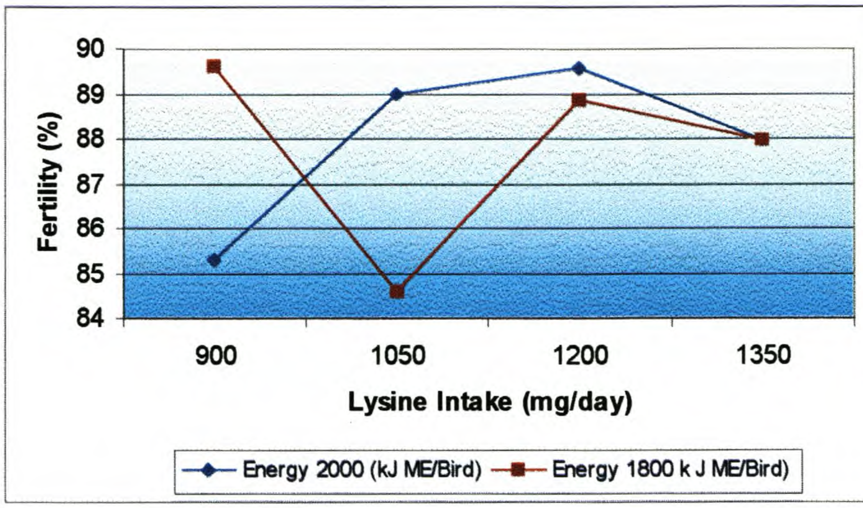


FIGURE 17: Response in Fertility to amino acid intake in period 3 (week 49 - 61) fed diets of different energy content.

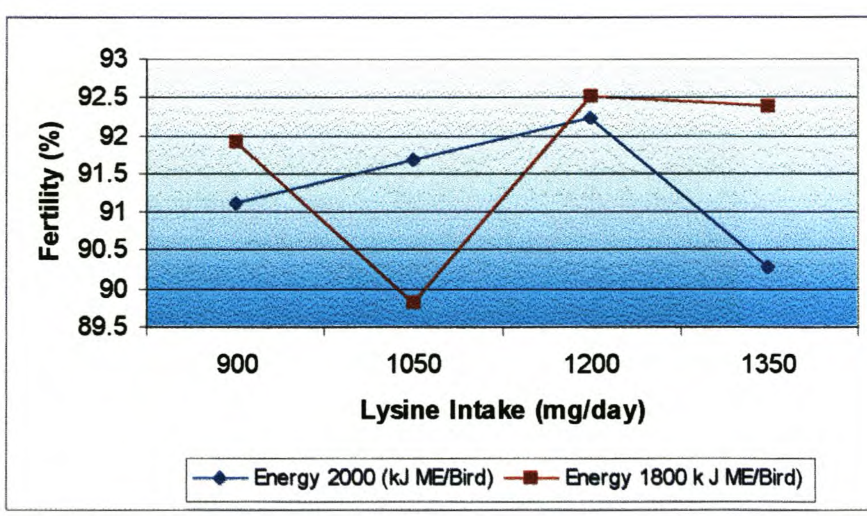


FIGURE 18: Response in Fertility to amino acid intake in the total period (week 23 - 61) fed diets of different energy content.

the testes for breeder males fed protein levels ranging from 9 to 18 %. In an experiment fed to adolescent broiler breeder males, diets containing 8,9 % (versus 16 % protein) diets significantly delayed sexual maturity but had no adverse effect on subsequent semen production, fertility or hatchability (Wilson et al., 1971). Conversely, Wilson et al., (1987a) reported that broiler breeder males fed a diet with 12 or 14 % protein starting at 4 weeks of age produced semen earlier and produced greater number of spermatozoa per ejaculate than did breeders fed a diet containing 16 to 18 % protein.

In this study, the response in fertility for the total period (Fig. 18) indicate that fertility was higher (non significant) for the birds receiving the lower energy diets with exception of the treatment receiving 1050 mg lysine per day. The body weight of the breeder hens receiving the high energy intake was significantly higher than the breeder standard (Fig. 40) and compared to the hens receiving the lower energy intakes (Fig. 41).

The effect of high energy intake and its consequence on body weight has been described as the main cause of low fertility associated with broiler breeder hens (Ingram & Wilson, 1987; McDaniel et al., 1981b; Harms 1984; Morris & Gous, 1988). Pearson & Herron (1981) observed a highly significant decrease in fertility associated with an energy intake of 1883 ME/bird/day in the last trimester of the laying cycle. At that time hens and cockerels were significantly heavier than birds fed 1519 kcal/bird/day. Wilson et al., (1983) found that if such heavy body weights is obtained before 30 weeks of age, then fertility is affected throughout the entire laying period. In contrast, Bilgili & Renden (1985) did not find this relationship between heavy body weight and low fertility. Katanbaf et al., (1989b) did not observe a difference in overall fertility in relation to level of feed allocation, however, duration of fertility was significantly lower in ad libitum fed hens. Hence, in naturally mating flocks, overweight hens may exhibit sperm storage difficulties, due to fat infiltration into sperm storage glands at the uterovaginal junction (McDaniel et al., 1981b). Ad libitum fed hens that lay erratically, frequently have more than one egg in the oviduct which may impede the normal movement of sperm from the uterovaginal junction to the site of fertilization.

3.5 HATCHABILITY:

Hatchability was adversely effected ($P < 0,05$) by the higher energy allowance (2000 kJ ME) for the total period of production (Fig. 22). This effect was very significant ($P < 0,01$) during the final period (week 49 - 61) of production and is illustrated in Fig. 21 (see addendum 17 - 20). This is in agreement with Bootwalla et al., (1983) who found that fertility and hatchability was significantly lower in ad libitum fed birds. This was also found earlier by Schumair & McGinnis (1969) and is in agreement with Blair et al., (1976). Bornstein et al., (1979) found that the rates of fertility and hatchability are not affected by dietary protein and energy levels within conventional ranges. They found that an increase in the incidence of early deaths during the first 5 days of incubation occurred on the highest energy allowance (1880 kJ AME/bird) in the last third of the laying period.

There is considerable evidence that embryo viability is affected by body weight. Allowing feed restricted broiler breeder hens to feed ad libitum for a period of 6 days immediately past peak production (34 weeks) resulted in a transient increase in the incidence of late-dead embryos (O'Sullivan et al.,1991). Most of the problems with embryo viability associated with body weight are related to the production of unsettable eggs, which exhibit poor hatchability. Chronically full-fed hens exhibit significantly reduced fertility and hatchability compared with hens that are feed restricted at typical industry levels (Yu et al., 1992). Ad libitum fed hens that lay erratically have reduced eggshell quality, presumable due to a loss of coordination of ovulation, oviposition and shell deposition (Jaap & Muir, 1968; Katanbaf et al., 1989) and hence would exhibit increased moisture loss during incubation and an increased incidence of embryonic mortality (McDaniel et al., 1981a). The high incidence of double - yolked eggs in overweight broiler breeders (Katanbaf et al., 1989b; Lilburn & Myers - Miller, 1990b; Yu et al., 1992) represents a further loss. Such eggs are of no value in terms of chicks production, due to poor embryo viability of multiple-yolked eggs.

Lopez & Leeson (1993) reported that a consistent feature of birds fed the low protein diets was improvement in hatchability. Hatchability of all eggs set improved linearly with a decrease in crude protein. Hatch of fertile also improved with low protein diets although the effect was less dramatic. The authors indicated that the major advantage to low protein diets is improved fertility, rather than improved embryo survival as originally proposed. The improved fertility may relate to greater control over body weight. Although not significant, Spratt (1987) found that increased protein allowance depressed hatchability, while the converse was seen with increased levels of energy.

In this investigation amino acid intake did not have a significant effect on hatchability. During the first and second period of production, the adverse effect of energy was only noticed at the higher amino acid intake (Fig. 19 - 20).

Pearson & Herron (1982) reported low hatchability between week 26 and 36 in birds fed high protein (27 g/bird/day) and low energy (1519 kJ ME/bird/day). This was due to a general increase in embryonic deaths in the second week of incubation and an increase in the number of "pipped" eggs. They suggested that embryo mortality at this age is likely to be caused by nutritional deficiency in the egg and that hatchability could be depressed when daily allowances of protein to energy exceeded 15 g : 1000 kJ/bird.

TABLE 11: **The mean response and statistical significance of Hatchability (%) to all treatments over the different periods of production**

(see addendum 17 - 20 for statistical analysis)

Daily Intake		**Age (Weeks)**			
Energy (kJ ME/Bird)	**Lysine (mg/Bird)**	**23 - 35**	**36 - 48**	**49 - 61**	**23 - 61**
2000	900	87,89	93,37	85,53	89,52
	1050	87,64	92,71	83,25	88,48
	1200	87,53	90,20	83,15	87,60
	1350	85,60	91,23	83,46	87,48
1800	900	87,48	92,94	87,99	89,80
	1050	88,06	92,89	87,83	89,98
	1200	88,32	94,10	88,08	90,62
	1350	89,26	94,19	86,66	90,60
Standard Deviation		**±3,100**	**±1,763**	**±3,701**	**±2,049**
Statistical Significance					
Energy (E)		NS	**	***	**
Protein (P)		NS	NS	NS	NS
Interaction: E x P		NS	NS	NS	NS

NS : Not significant

**** : P < 0,05**

***** : P < 0,01**

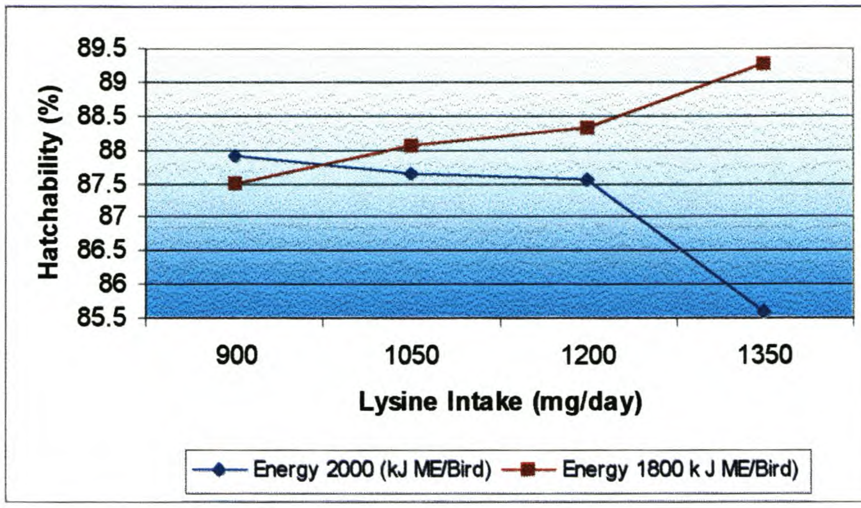


FIGURE 19: Response in Hatchability to amino acid intake in period 1 (week 23 - 35) fed diets of different energy content.

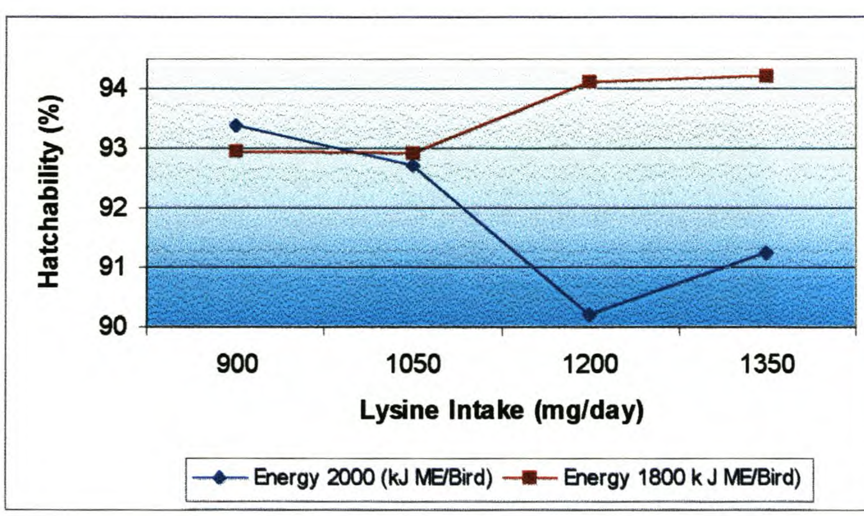


FIGURE 20: Response in Hatchability to amino acid intake in period 2 (week 36 - 48) fed diets of different energy content.

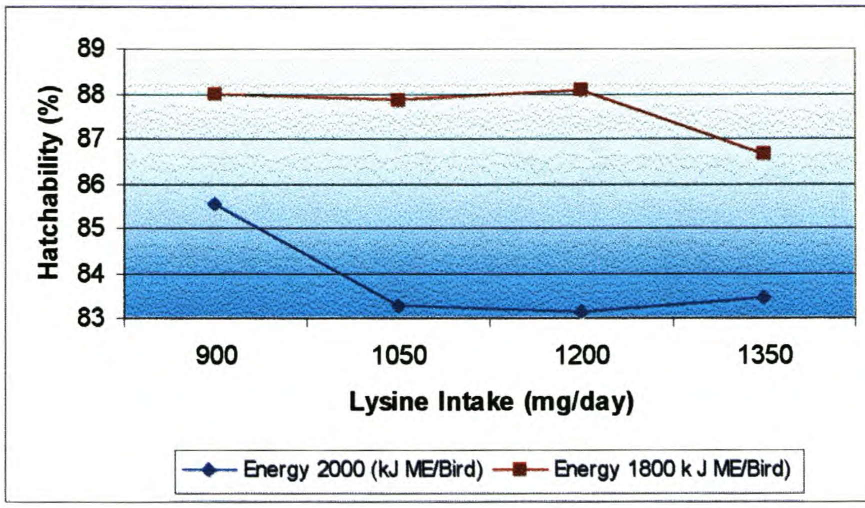


FIGURE 21: Response in Hatchability to amino acid intake in period 3 (week 49 - 61) fed diets of different energy content.

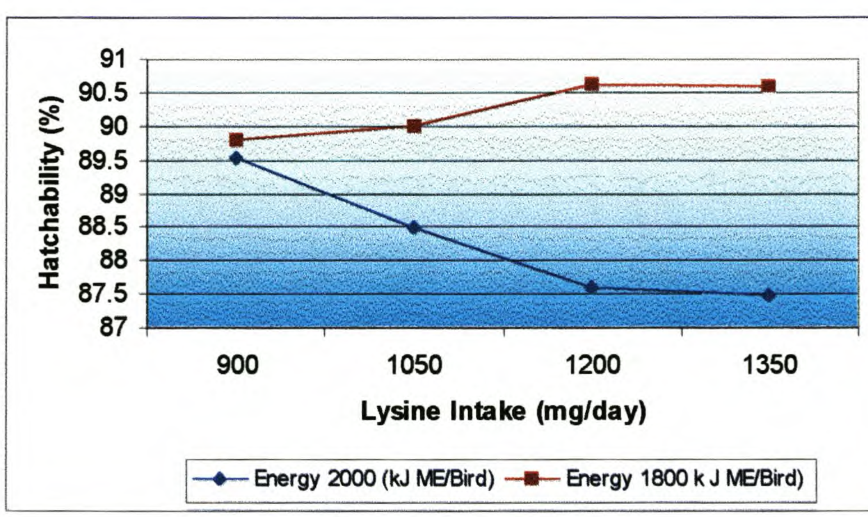


FIGURE 22: Response in Hatchability to amino acid intake in the total period (week 23 - 61) fed diets of different energy content.

McNaughton et al., (1978) found that hatchability decreased as egg weights increased. These results are comparable with data reported by Hays (1955a). No significant differences in hatchability were found due to age of parents when egg weights remained the same.

3.6 CHICK PERFORMANCE :

As expected, the amount of chicks per hen housed produced is similar to the results of hen day production (Table 12). Energy had a significant ($P < 0,05$) negative effect on the amount of chicks produced during the third period of production (Fig. 25). Although not significant, energy had a positive effect on the amount of chicks produced during production period 1 and 2 (Fig. 23 - 24). The negative effect of high energy and protein levels on fertility and hatchability did affect the amount of chicks produced. It resulted in the effect of energy and protein being more pronounced on chicks produced than on hen day production.

The best results were recorded at the lower energy level and daily amino acid intake of 1200 mg lysine, throughout the laying period. The highest amino acid allowance

TABLE 12: **The effect of different combinations of energy and lysine on Chicks (chicks/hen/week) of broiler breeder females during different periods of production** (see addendum 21 -24 for statistical analysis)

Daily Intake		**Age (Weeks)**			
Energy (kJ ME/Bird)	**Lysine (mg/Bird)**	**23 - 35**	**36 - 48**	**49 - 61**	**23 - 61**
2000	900	2,57	3,74	2,43	2,93
	1050	2,52	3,81	2,47	2,93
	1200	2,45	3,83	2,41	2,89
	1350	2,27	3,63	2,22	2,71
1800	900	2,31	3,63	2,56	2,83
	1050	2,41	3,65	2,54	2,87
	1200	2,66	4,10	2,75	3,17
	1350	2,54	3,79	2,67	2,99
Standard Deviation		**±0,217**	**±0,229**	**±0,329**	**±0,196**
Statistical Significance					
Energy (E)		NS	NS	**	NS
Protein (P)		NS	NS	NS	NS
Interaction: E x P		NS	NS	NS	NS

NS : Not significant

**** : P < 0,05**

***** : P < 0,01**

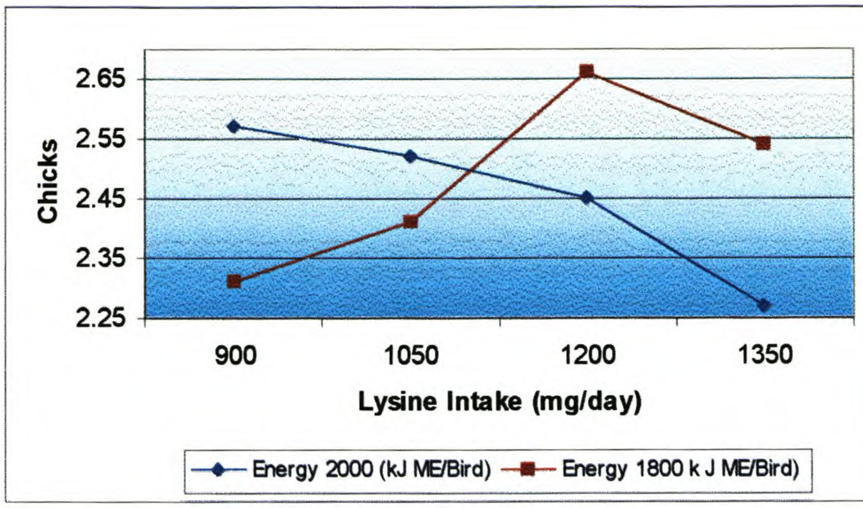


FIGURE 23: Response in Chicks to amino acid intake in period 1 (week 23 - 35) fed diets of different energy intake.

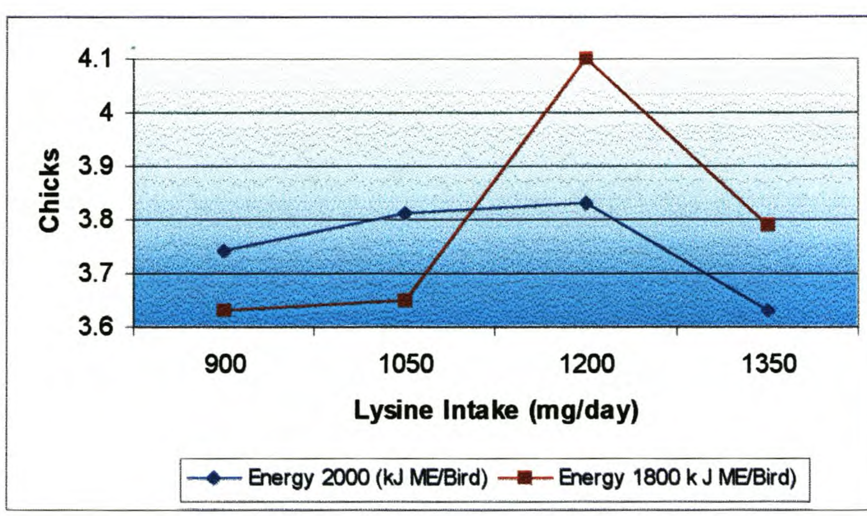


FIGURE 24: Response in Chicks to amino acid intake in period 2 (week 36 - 48) fed diets of different energy content.

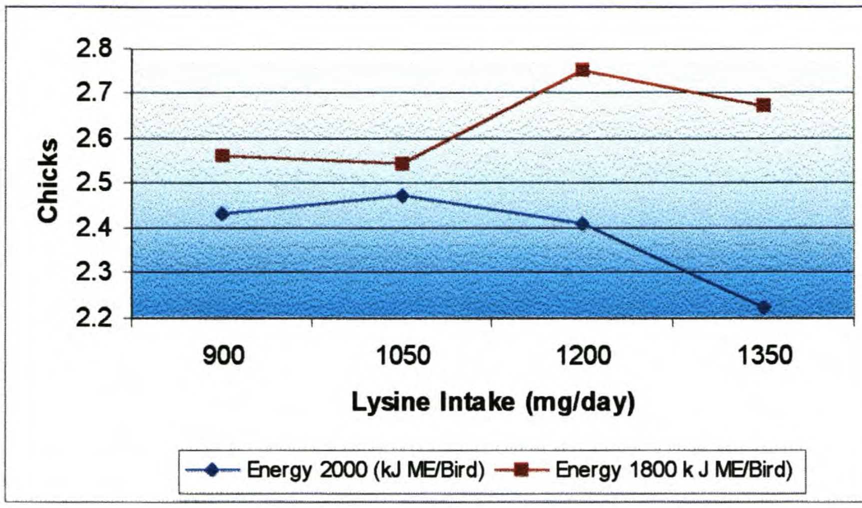


FIGURE 25: Response in Chicks to amino acid intake in period 3 (week 49 - 61) fed diets of different energy content.

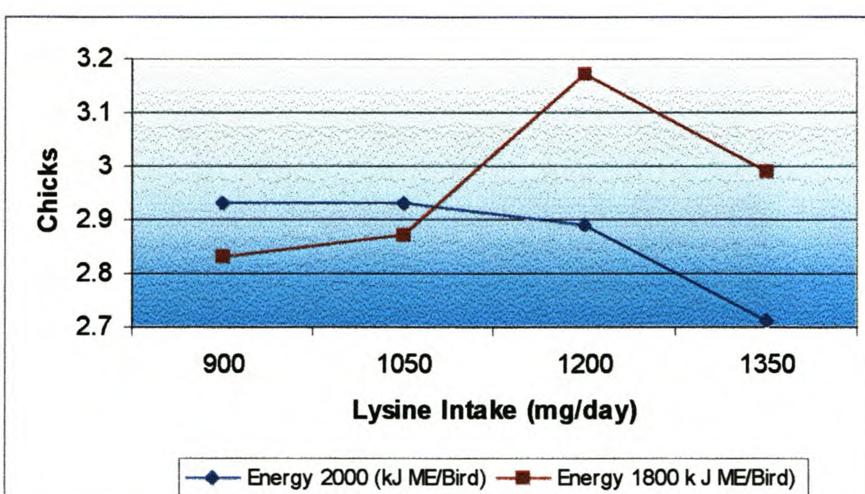


FIGURE 26: Response in Chicks to amino acid intake in the total period (week 23 - 61) fed diets of different energy content.

at the lower energy level resulted in ten more chicks being produced over the total period than the comparative amino acid allowances at the higher energy level (Fig. 26).

Spratt & Leeson (1987) monitored the effect of protein and energy intake on the composition of broiler breeder eggs. Yolk accounted for a larger percentage of total egg weight as hens aged and also when hens were fed a high energy allowance. A 7 - 8 % increase in the amount of egg yolk was found when energy increased from 1360 to 1611 and 1883 kJ ME/day. This could provide about 2,9 g of fat in a 62 g egg. Greater yolk carry over via the yolksac by the day old chick would likely increase nutrient storage reserves and so improve survival and early growth rate. McNaughton et al., (1978) also reported that chicks produced by 58 week old broiler breeders had a higher proportion of body fat than did chicks produced from 29 week old broiler breeders when hatching egg weight remained the same ($P \leq 0{,}01$). Therefore, the effect of broiler breeder age on broiler growth may in part be related to yolk storage in newly hatched chicks.

Spratt & Leeson (1987) also indicated the importance of maintaining an adequate energy : protein ratio prior to peak egg production. During week 28 an energy : protein ratio of 17 : 1 to 18 : 1 was associated with heavier chicks, while ratios outside this range resulted in a substantial decline in chick weight.

A high positive relationship between egg weight and chick size has been reported by several workers (Shanaway, 1984, 1987; Morris et al., 1968; Wiley, 1950; Goodwin, 1961; Washburn & Guill, 1974 and Pinchasov, 1991) and chick weight is usually 62 - 76 % of egg weight (Morris et al, 1968; Pinchasov, 1991; O'Neil, 1955; Whiting & Pesti, 1983 and Wilson, 1991). In the present study this correlation was also found to be very significant ($P < 0,01$). The regression equation is as follows : Chick Weight = 10,5 + 1,22 x Egg Weight ($R^2 = 0,69$) and this is illustrated in Fig. 27. In this experiment the chick weight was between 70 - 74 % of the egg weight.

The highest amino acid levels at both energy levels had a significant ($P < 0,01$) positive effect on the weight of chicks at day old (Fig. 31). The higher energy levels had a additional significant ($P < 0,01$) positive effect on chick weights (Fig. 28 - 30). The positive effect of energy seems to decline at the higher amino acid levels (see addendum 25 - 28). The results of chick weight are as expected in correlation with the results of the average egg weight.

As mentioned Lopez & Leeson (1993) also found a reduction in egg size at lower levels of protein intake. This reduction in egg size can be of concern for chick size and subsequent broiler growth characteristics. Chick size was reduced in correlation with a reduction in egg size and this resulted in slower initial broiler growth, especially for the male birds. However by 49 days of age there was no significant difference in either male or female body weight. Some studies have shown that chick weight at hatch affects subsequent broiler growth (Morris et al., 1968;

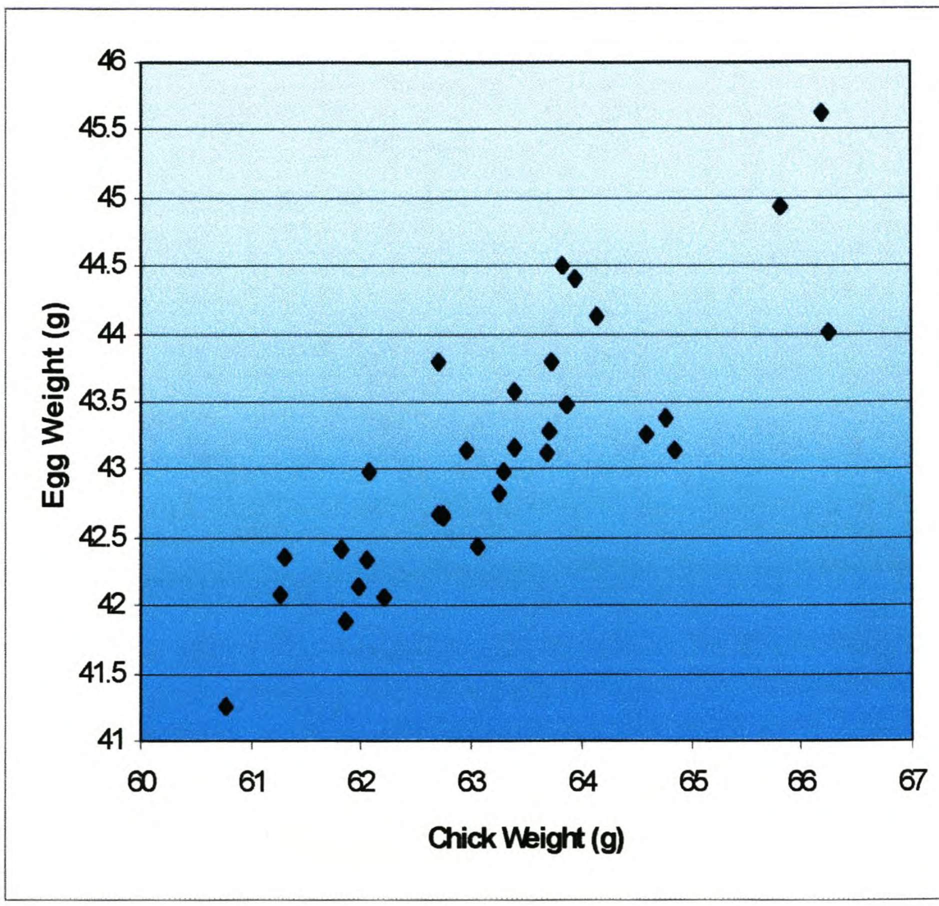


FIGURE 27 : The relationship between egg weight and chick weight.

Wiley, 1950; Goodwin, 1961; O'Neil, 1950; Proudfoot & Hulan, 1981 and Wyatt et al., 1985) while others have shown any residual affect of chick weight to quickly disappear (Washburn & Guill, 1974; Pinchasov, 1991; Godfrey et al., 1953 and Kosin et al., 1952). It has been reported that a 1 g difference in egg weight results in some 10 - 12 g difference in body weight at 8 to 9 weeks (Goodwin, 1961 and Al - Murrani, 1978). Because chick size is positively correlated with egg size, it seems reasonable to assume that changes in the diet which influence egg weight will also influence the size of the chick at hatch. However, whether or not breeder nutrition modifies subsequent broiler performance is still not clear. Wilson & Harms (1984) found that protein intake of 19,9 to 23 g/bird/day had no effect on 49 day body weight of offspring. Similar results were observed by both Spratt & Leeson (1987) and Pearson & Herron (1981). They also reported a lack of effect of energy intake from 1360 to 1883 kJ/bird/day on broiler weight at 41 and 48 days. A better understanding of the effect of maternal diet on broiler performance depends on controlling the confounding influence of egg weight and age of bird.

TABLE 13: **The effect of different combinations of energy and lysine on Chick Weight (g) of broiler breeder females during different periods of production**

(see addendum 25 - 28 for statistical analysis)

Daily Intake		**Age (Weeks)**			
Energy (kJ ME/Bird)	**Lysine (mg/Bird)**	**23 - 35**	**36 - 48**	**49 - 61**	**23 - 61**
2000	900	39,87	43,62	47,10	43,32
	1050	39,89	43,67	46,57	43,31
	1200	39,78	43,64	46,22	43,15
	1350	40,43	44,71	47,79	44,28
1800	900	37,91	42,69	45,52	42,17
	1050	38,67	43,05	45,13	42,40
	1200	39,69	42,62	45,80	42,68
	1350	40,39	44,20	47,44	43,84
Standard Deviation		**±0,773**	**±0,881**	**±1,191**	**±0,738**
Statistical Significance					
Energy (E)		***	**	**	***
Protein (P)		***	**	**	***
Interaction: E x P		NS	NS	NS	NS
NS : Not significant **** : P < 0,05** ***** : P < 0,01**					

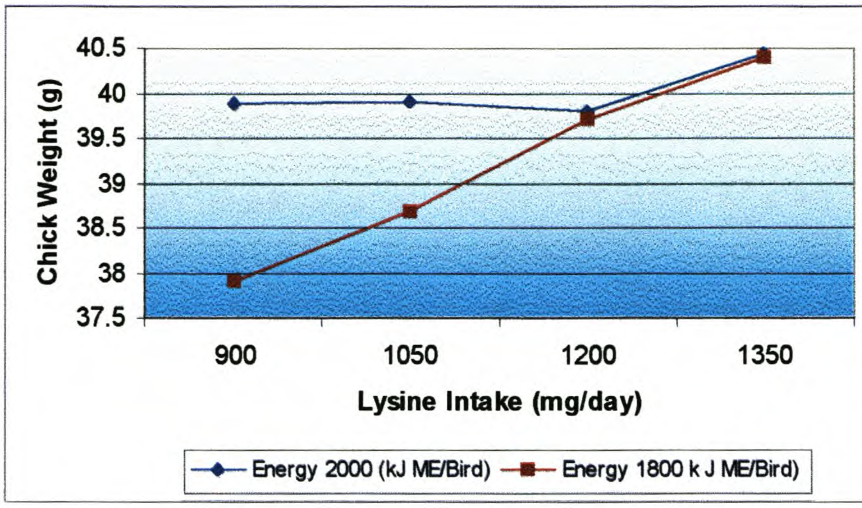


FIGURE 28: Response in Chick Weight to amino acid intake in period 1 (week 23 - 25) fed diets of different energy content.

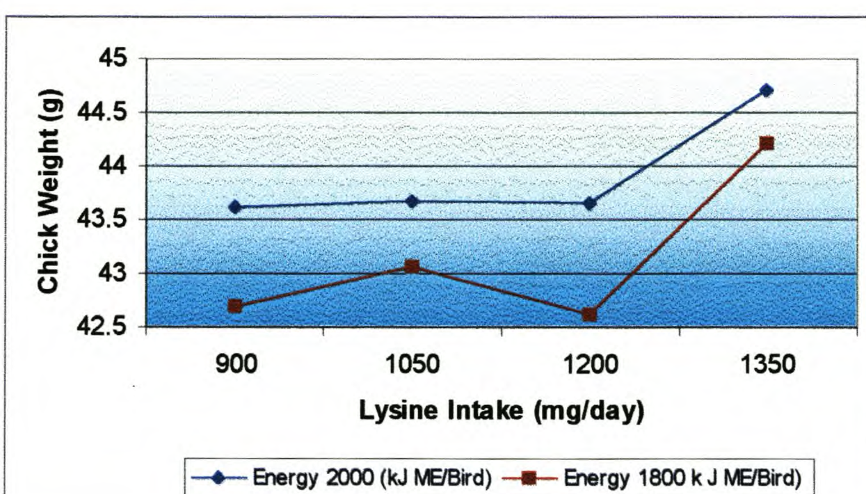


FIGURE 29: Response in Chick Weight to amino acid intake in period 2 (week 36 - 48) fed diets of different energy content.

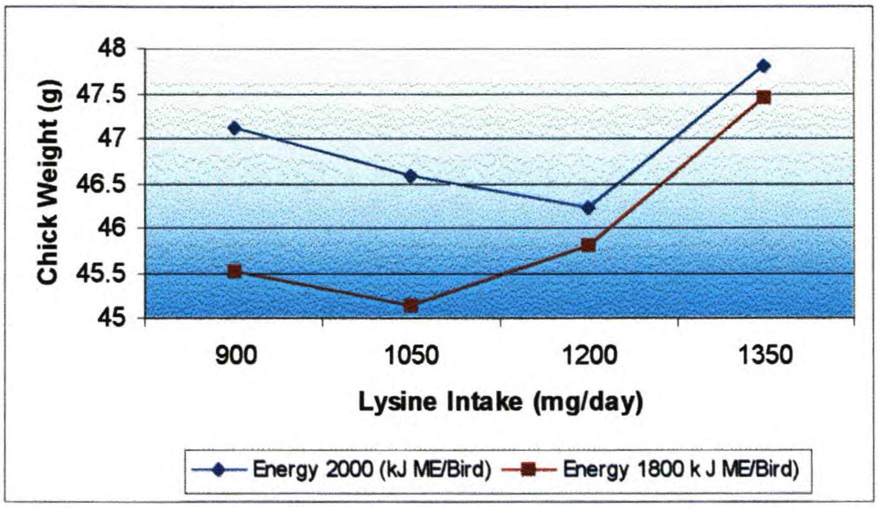


FIGURE 30: Response in Chick Weight to amino acid intake in period 2 (week 49 - 61) fed diets of different energy content.

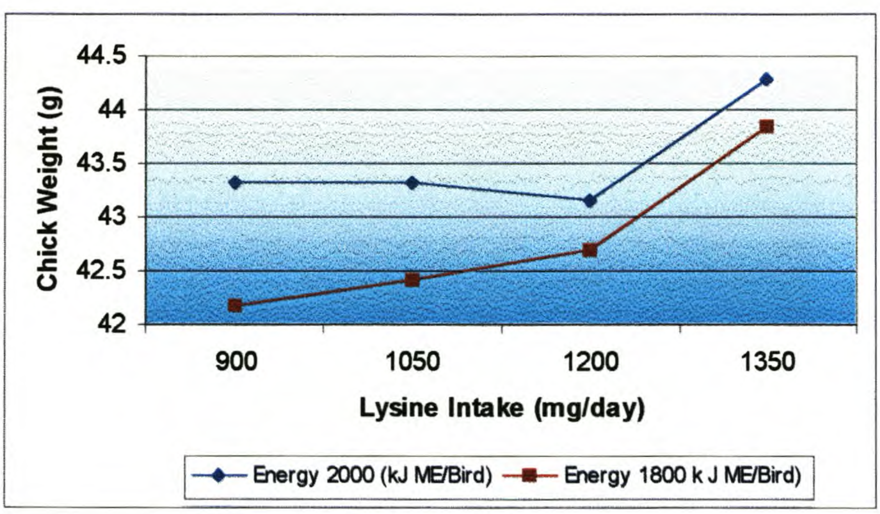


FIGURE 31: Response in Chick Weight to amino acid intake in the total period (week 23 - 61) fed diets of different energy content.

3.7 FEED CONVERSION:

The feed conversion was significantly ($P < 0,01$) higher at the lower amino acid levels (Table 14) during the total period of production. The high energy level also resulted in a significant ($P < 0,01$) higher feed conversion during the first period of production (Fig. 32). At the final period of production (week 49 - 61) the high energy level had a negative effect on the feed conversion (Fig. 31).

3.8 BODY WEIGHT:

Control over immature body weight seems critical for the performance of broiler breeders. Pearson & Herron (1980) found that by controlling body weight gain early in lay, maintenance requirement was reduced. Feed restriction of female broiler breeders during the rearing period have been showed to delay sexual maturity (Robbins et al., 1986; Wilson & Harms, 1986; Ingram & Wilson, 1987 and Yu et al., 1992).

The attainment of sexual maturity is governed by body weight (Brody et al., 1980, 1984), body fat (Bornstein et al., 1984), body fat free mass or lean body mass (Soller et al., 1984), photoperiod (Chaney & Fuller, 1975) and age (Brody et al., 1980,

TABLE 14: **The effect of different combinations of energy and lysine on Feed Conversion (g) of broiler breeder females during different periods of production** (see addendum 29 - 32 for statistical analysis).

Daily Intake		**Age (Weeks)**			
Energy (kJ ME/Bird)	**Lysine (mg/Bird)**	**23 - 35**	**36 - 48**	**49 - 61**	**23 - 61**
2000	900	38,37	48,58	43,08	43,41
	1050	33,72	43,08	37,60	38,07
	1200	29,65	37,96	32,42	33,34
	1350	26,31	35,15	27,40	29,66
1800	900	34,67	47,99	41,86	41,50
	1050	31,91	41,86	37,63	37,13
	1200	29,14	37,85	34,06	33,70
	1350	25,82	33,72	31,44	30,11
Standard Deviation		**±1,575**	**±1,738**	**±2,665**	**±1,277**
Statistical Significance					
Energy (E)		***	NS	NS	NS
Protein (P)		***	***	***	***
Interaction: E x P		NS	NS	NS	NS
NS : Not significant **** : P < 0,05** ***** : P < 0,01**					

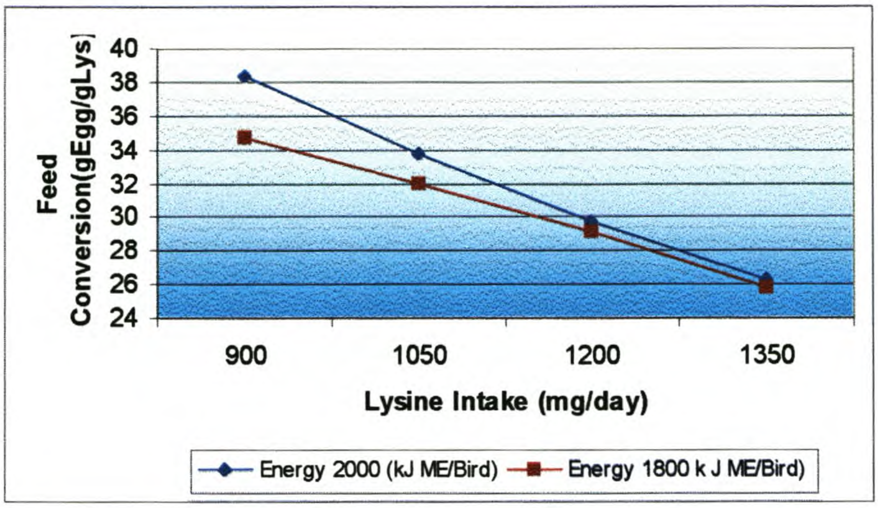


FIGURE 32: Response in Feed Conversion to amino acid intake in period 1 (week 23 - 35) fed diets of different energy content.

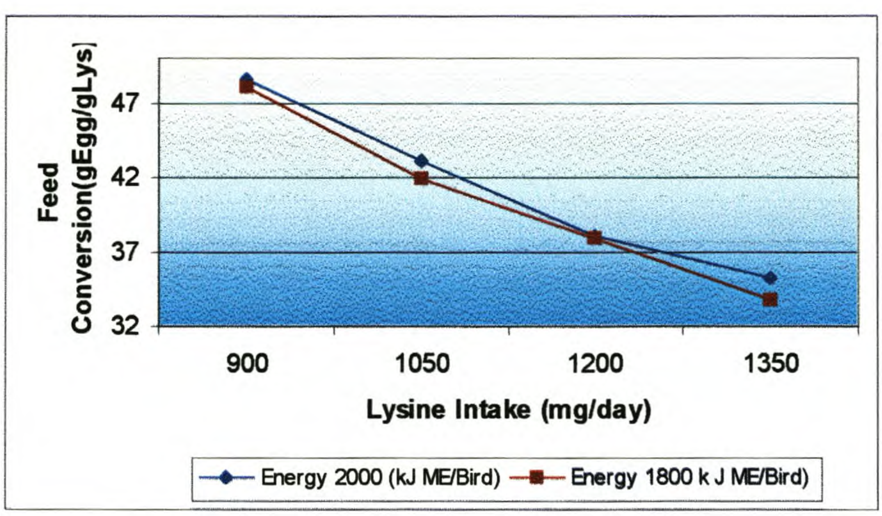


FIGURE 33: Response in Feed Conversion to amino acid intake in period 2 (week 36 - 48) fed diets of different energy content.

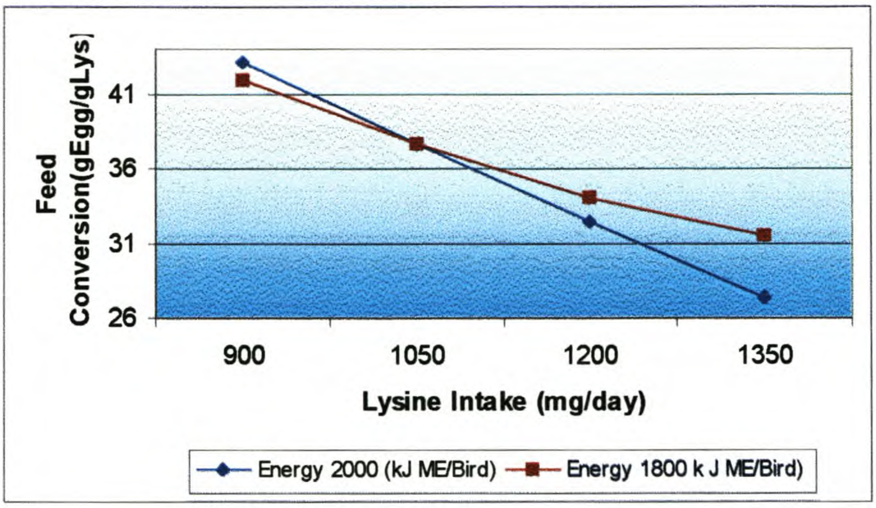


FIGURE 34: Response in Feed Conversion to amino acid intake in period 3 (week 49 - 61) fed diets of different energy content.

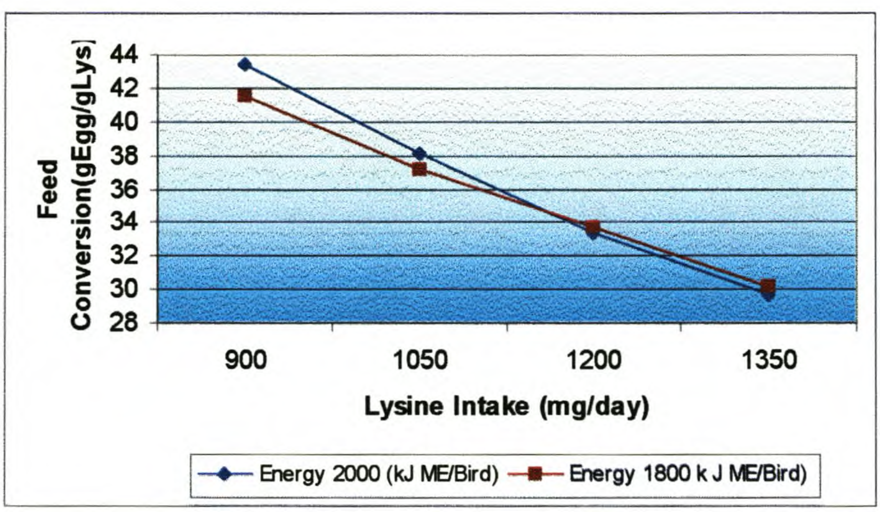


FIGURE 35: Response in Feed Conversion to amino acid intake in the total period (week 23 - 61) fed diets of different energy content.

1984). Katanbaf et al., (1989b) also observed that broiler breeders that are full-fed are dependent upon reaching a critical age to start laying, whereas feed restricted hens that commence lay later, are dependent upon attaining critical body weight and carcass fat stores. In chickens the secretion of the luteinising hormone, which is essential for ovulation, may be linked with the attainment of a particular body size (Buonomo et al., 1982).

It is generally recognized that each commercial strain of bird has an optimum weight at the time of approaching sexual maturity and for most strains this is around 2,2 kg at 22 weeks of age. In fact the best performing flocks are invariably slightly heavier at this age, regardless of strain. Birds used by Brake et al., (1985) were around the breeder's recommended weight and did not respond to pre-breeder nutrition. It can therefore be generalized that pre-breeder diets may be of use where rearing programs have been inadequate and birds are underweight at the time of move to the breeder house.

In this experiment all the birds received the same ration until 22 weeks of age. The experimental diets did not appear to influence production traits until week 27. At week 25 the birds receiving the high energy diet was already significantly heavier than the birds receiving the low energy diets (Fig. 40 and 41). The egg production

TABLE 15: **The effect of different combinations of energy and lysine on Female body weight (g) of broiler breeder females different periods of production**
(see addendum 33 - 36 for statistical analysis)

Daily Intake		**Age (Weeks)**			
Energy (kJ ME/Bird)	**Lysine (mg/Bird)**	**23 - 35**	**36 - 48**	**49 - 61**	**23 - 61**
2000	900	3455	3822	4097	3791
	1050	3471	3735	4017	3741
	1200	3576	3858	4108	3847
	1350	3611	3894	4157	3888
1800	900	3203	3400	3457	3353
	1050	3300	3511	3625	3478
	1200	3327	3500	3637	3488
	1350	3407	3616	3857	3627
Standard Deviation		**±82,23**	**±118,6**	**±201,7**	**±110,7**
Statistical Significance					
Energy (E)		***	***	***	***
Protein (P)		***	NS	NS	**
Interaction: E x P		NS	NS	NS	NS
NS : Not significant					
**** : P < 0,05**					
***** : P < 0,01**					

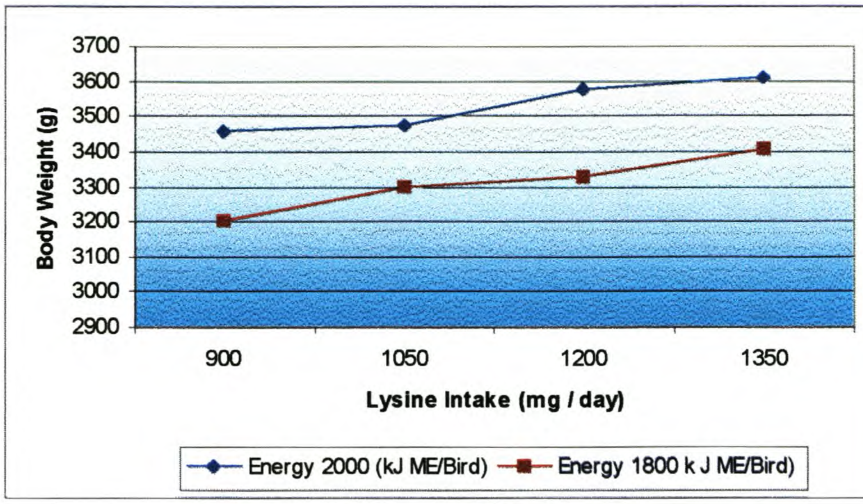


FIGURE 36 : Response in Hen body weight to amino acid intake in period 1 (week 23 – 35) fed diets of different energy content.

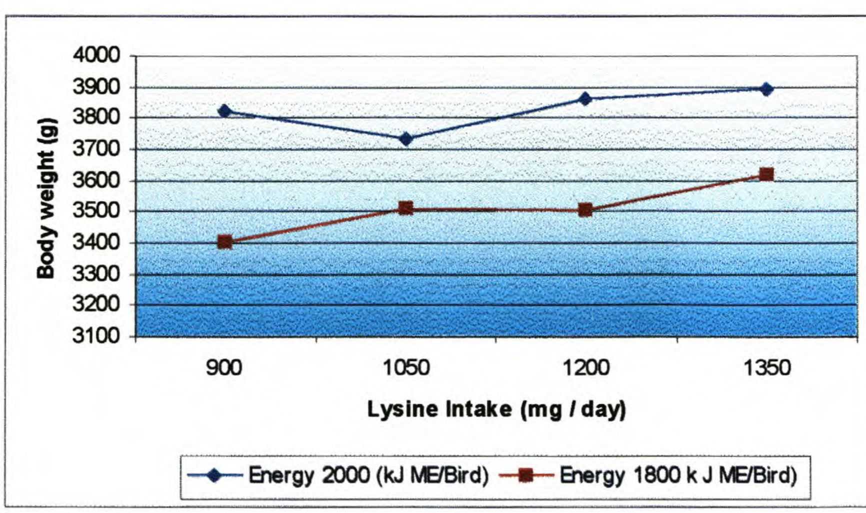


FIGURE 37 : Response in Hen body weight to amino acid intake in period 2 (week 36 - 48) fed diets of different energy content.

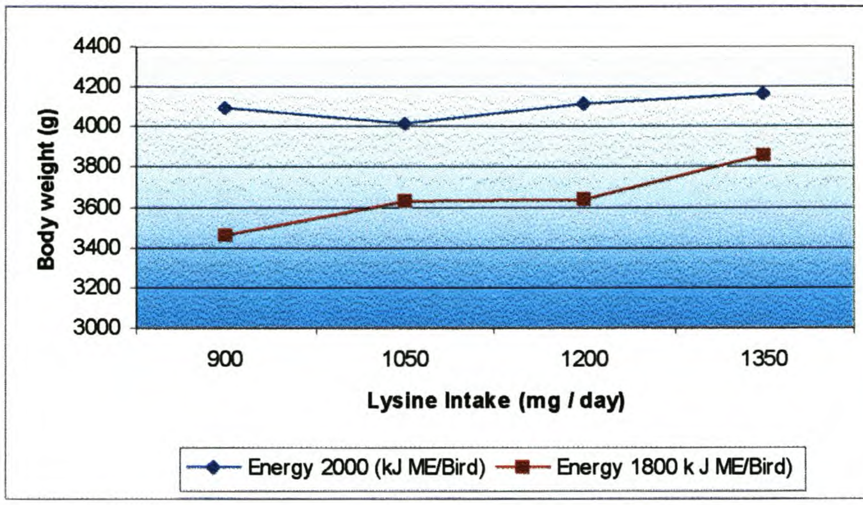


FIGURE 38 : Response in Hen body weight to amino acid intake in period 3 (week 49 – 61) fed diets of different energy content.

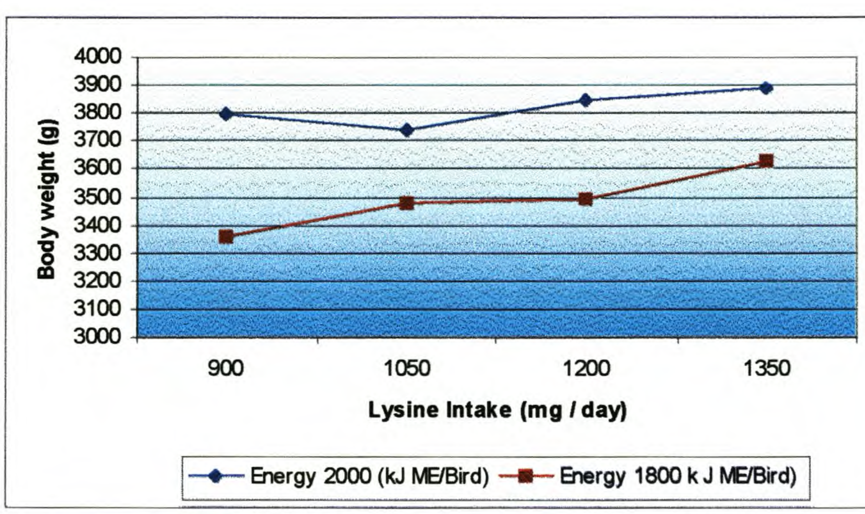


FIGURE 39 : Response in Hen body weight to amino acid intake in the total period (week 23 – 61) fed diets of different energy content.

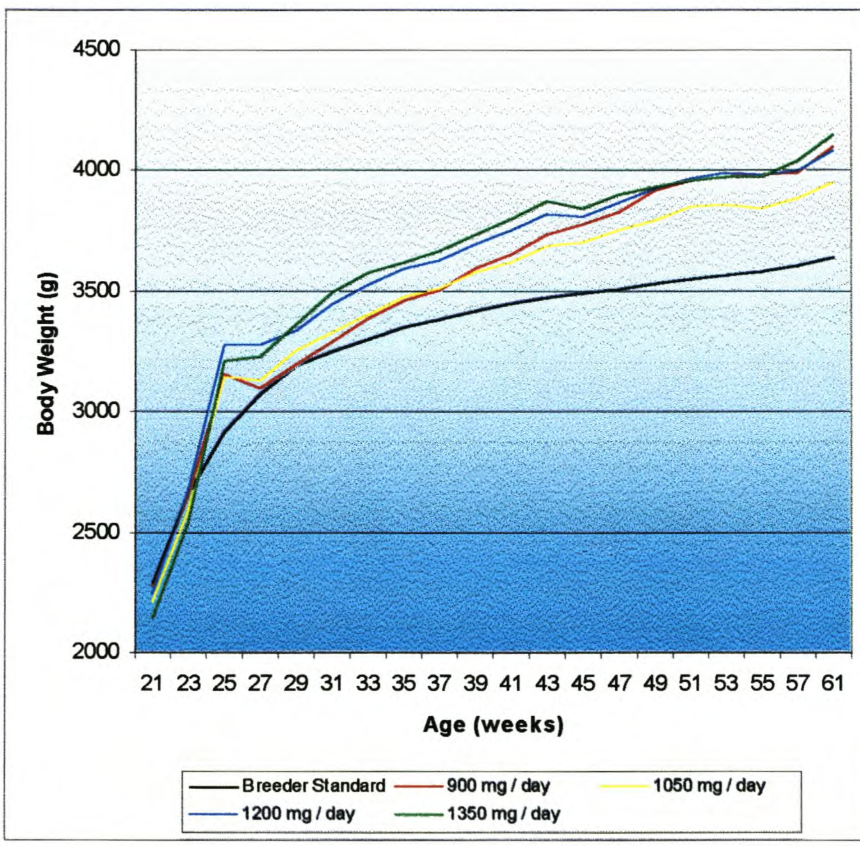


FIGURE 40: The average live body weight (g) of the female on the high energy diets (2000 kJ/day).

of the heavier hens was also higher, although not significantly, during the peak period of production.

Adequate nutrition for the young pullet can definitely help to increase egg numbers. Harms (1984) studied 49 commercial breeder flocks and clearly demonstrated that adequate body weight in the young breeder pullet is critical for optimum performance. This data also support the need of the young breeder female for some nutrient reserves. The key nutrient under these conditions is most likely energy, because as with the Leghorn pullet, the broiler breeder is in a somewhat delicate balance regarding energy input and energy expenditure (Leeson and Summers, 1991).

After maturity, broiler breeders tend to eat more rapidly and gain weight to develop all their reproductive organs, displaying a remarkable compensatory growth (Lopez & Leeson, 1994). A body weight gain of 1,1 kg from 21 to 36 weeks of age has been associated with optimum performance (Pearson & Herron, 1981). Bornstein et al., (1979) suggested that the average daily weight gain of the hens during the 30 to 50 week age period should not drop below 3,0 g in order to ensure an optimal rate of production. In this experiment from 31 weeks to 51 weeks of age the daily weight gain was 3,9 g/day for the higher energy diets and 2,8 g/day for the lower energy diets. Both were higher than the breeder indication of 2,13 g/day. Pearson & Herron

TABLE 16: **The average live body weight (g) of the females in the 8 treatments and the standard at 20 different ages.**

Treatments									
Age Weeks	**Stan-dard**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
21	2290	2270	2203	2237	2138	2168	2168	2199	2145
23	2660	2646	2585	2668	2540	2497	2478	2525	2475
25	2920	3151	3140	3272	3206	2924	3010	3067	3014
27	3080	3096	3126	3273	3226	2904	2961	3039	2989
29	3190	3189	3251	3329	3361	2987	3046	3115	3167
31	3250	3284	3327	3440	3493	3076	3124	3229	3265
33	3300	3380	3395	3522	3574	3156	3232	3294	3344
35	3350	3453	3470	3589	3611	3202	3302	3324	3401
37	3383	3500	3505	3624	3662	3223	3332	3361	3424
39	3416	3589	3570	3692	3727	3255	3391	3404	3471
41	3450	3646	3617	3744	3796	3290	3422	3420	3467
43	3470	3726	3681	3814	3868	3311	3468	3443	3539
45	3490	3771	3699	3807	3841	3322	3466	3448	3542
47	3510	3822	3746	3861	3894	3399	3507	3497	3606
49	3533	3915	3792	3923	3929	3443	3580	3541	3647
51	3548	3952	3845	3963	3956	3433	3597	3566	3662
53	3566	3971	3852	3985	3973	3425	3586	3571	3676
55	3585	3977	3839	3981	3974	3398	3571	3581	3729
57	3603	3983	3882	3998	4035	3418	3580	3608	3760
61	3640	4093	3943	4081	4143	3459	3623	3634	3848

(1980) also indicated that a gradual increase in body weight and fat deposition over the laying period was beneficial.

For mature birds, body weight gain has been related to excessive intake of energy rather than to protein intake (Pearson & Herron, 1980, 1982; Wilson & Harms, 1986). However, protein intake has also been reported to have an effect on body weight. Spratt & Leeson (1987) reported a minimal effect of dietary protein intake on body weight and Harms & Yvey (1992) reported a more substantial effect. Furthermore, as discussed earlier, Lopez & Leeson (1993) found improved fertility on lower protein diets. The reason is thought to be due to the fact that these birds gained less weight. This would also suggests that protein (amino acid) intake of the breeder hen is related to weight gain, and that excessive weight gain after peak egg production is not merely a factor of energy balance.

In this experiment energy had a significant ($P < 0,05$) effect on body weight (Table 15) through the total production period (week 23 - 61) and protein had a very significant ($P < 0,01$) effect during the first period of production. At the lower energy diets, the highest amino acid intake produced the heaviest birds and the opposite was noticed at the lowest amino acid intake (Fig. 36 - 39). At the higher energy diets the birds receiving the two highest amino acid levels showed a higher gain in body weight.

The absolute energy intake associated with optimum production will depend upon a bird's actual maintenance requirement. This is likely to differ between cage and floor systems as well as between strains. It has been suggested (Pearson & Herron, 1981) that, under restricted feeding systems, body weight could be used as an indicator of the adequacy of an energy allowance in meeting a bird's requirements for production.

It was noticed in this experiment that at week 27 there was a decline in the body weight of the hens and the cockerels. This was however corrected at week 29 (Fig. 40 - 43). This could be a result of the feed allowance not being sufficient at the period just prior to peak production (week 25 to 27). It has been shown that failure to lead feed for egg production, results in the bird utilizing its body fat reserves to supplement the nutrient supply in the feed. If this scenario continues for long enough, all labile energy reserves are utilized, and the bird shows a characteristic loss or stalling in weight that immediately precedes loss in production, assuming the bird has energy reserves to utilize (Leeson & Summers, 1991). Underfeeding results in very short term peaks, of only 3 to 4 weeks, and these are usually associated with the classical sign of loss or stall-out in body weight for 1 to 2 weeks.

TABLE 17: **The average live body weight (g) of the cockerels in the 8 treatments and the standard at 20 different ages.**

Treatments									
Age Weeks	Stan- dard	A	B	C	D	E	F	G	H
21	3150	3440	3227	3315	3225	3145	3197	3316	3312
23	3370	3640	3439	3510	3596	3356	3489	3590	3563
25	3650	3955	3744	3777	3830	3558	3736	3904	3887
27	3900	3802	3783	3678	3700	3698	3984	3812	3775
29	4070	3851	3895	3782	3772	3769	4054	4011	3896
31	4200	3962	4042	3964	4003	3852	4237	4240	4119
33	4290	4013	4208	4162	4123	3903	4346	4292	4438
35	4350	4063	4347	4214	4160	3951	4503	4387	4521
37	4388	4114	4418	4216	4263	4047	4405	4427	4506
39	4426	4131	4449	4272	4243	4079	4298	4505	4502
41	4465	4161	4455	4302	4245	4182	4552	4565	4540
43	4496	4176	4521	4343	4244	4238	4364	4591	4559
45	4527	4211	4590	4394	4300	4228	4467	4677	4606
47	4558	4370	4606	4449	4301	4175	4419	4589	4660
49	4589	4453	4658	4457	4367	4175	4597	4620	4743
51	4620	4485	4671	4458	4404	4213	4715	4598	4802
53	4660	4575	4694	4470	4434	4240	4691	4718	4925
55	4700	4661	4857	4524	4453	4252	4735	4742	4983
57	4740	4602	4894	4582	4457	4257	4707	4723	4938
61	4820	4568	4914	4680	4624	4346	4652	4786	4902

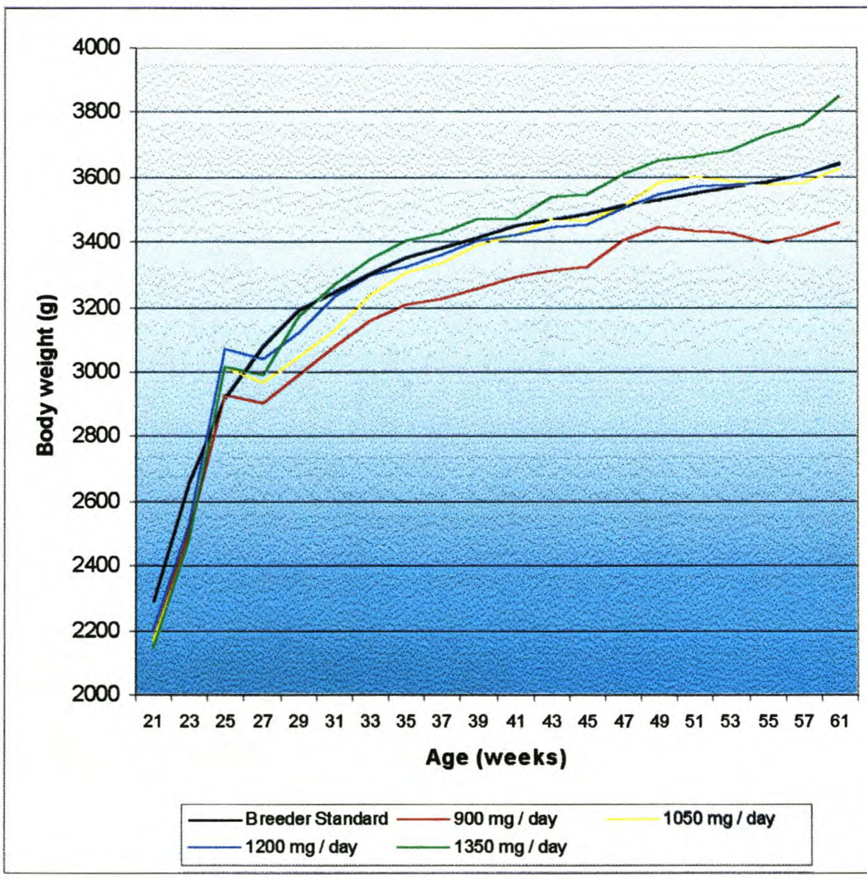


FIGURE 41: The average live body weight (g) of the females on the low energy diets (1800 kJ/day).

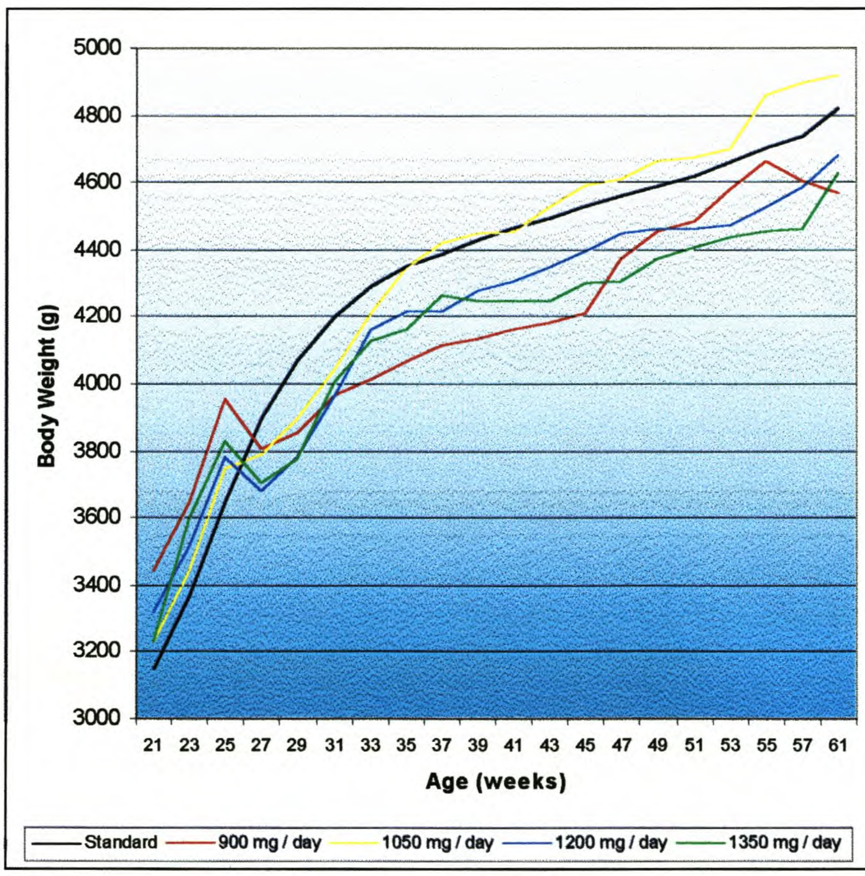


FIGURE 42: The average live body weight (g) of the males on the high energy diets (2000 kJ/day).

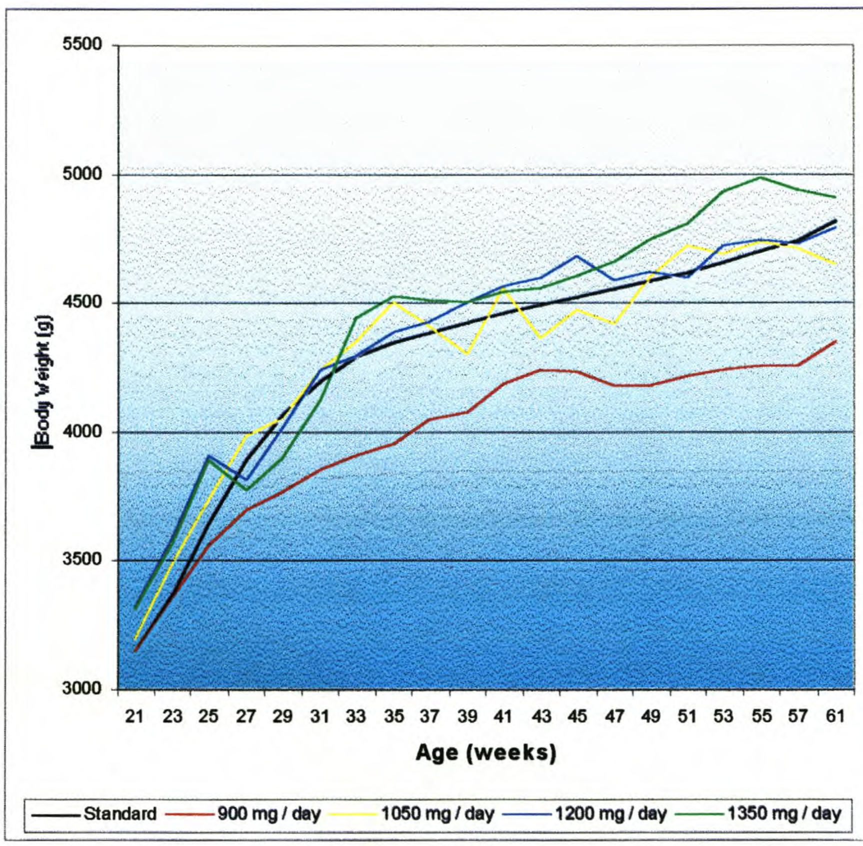


FIGURE 43: The average live body weight (g) of the males on the low energy diets (1800 kJ/day).

Chapter 3

THE EFFECT OF DIFFERENT DIETARY LEVELS OF ENERGY AND PROTEIN ON THE BODY COMPOSITION OF BROILER BREEDERS

1. INTRODUCTION

Knowledge of the effects of management and feeding regime on body composition of broiler breeders is becoming increasingly important. Application of this knowledge is possible only if there are simple practical measurements for estimation of body composition.

It is often important to be able to predict body composition of poultry, particularly for serial determinations and in association with other physiological and production measurements. However, it is usually expensive and time consuming to slaughter birds and large numbers are needed to measure small changes in composition and for statistical interpretation of the results (Johnson & Farrell, 1988).

Indirect methods are usually more accurate than using changes in live weight to predict changes in chemical composition of livestock since there are sometimes differences in the relations between live weight and chemical components (Searle, 1970; Van Gils et al., 1977). Various techniques have been used to estimate body composition in vivo, one of the most promising appears to be the measurement of water space using tritiated water. Numerous studies have been carried out with a range of animal species on the application of isotope dilution techniques, usually with the water isotopes tritiated water or deuterium oxide. Isotope dilution is used to estimate total body water, and because this varies inversely with body fat content on a live weight basis, the latter can usually be predicted from the former with acceptable accuracy, for example sheep (Panaretto, 1963), cattle (Little & McLean, 1981), pigs (Houseman et al., 1973), goats (Panaretto & Till, 1963) and poultry (Farrel, 1974; Johnson & Farrel, 1988).

The liquid with the isotope hydrogen ^{3}H in the water molecule is radio active and known as tritiated water. Injecting this liquid into the bird disperses the activity in the body fluids of the bird so that it is proportionally diluted. The activity of the body water is determined after a constant time of dilution through the body. The dilution that has taken place is used to calculate the total body water content of the bird.

The present experiment was carried out in an attempt to correlate changes in carcass composition with energy and lysine consumption during the production cycle of broiler breeders. In other words, whether calculated expenditure of energy for maintenance, growth, egg output and fat deposition could be accounted for from dietary intake.

2. MATERIALS AND METHODS:

2.1 BIRDS AND MANAGEMENT:

The same birds and dietary treatments as reported on in Chapter 2 were used. One third of each pen's birds were chosen at random for the determination of body composition. At 26, 35, 43, 52 and 61 weeks of age body composition was determined by injecting tritiated water and measuring the dilution which gives an estimate of the total body water content. The same birds were used throughout the experiment and were leg-banded when the experiment started.

2.2 ISOTOPE INJECTION AND BLOOD SAMPLING:

The same procedure according to Johnson & Farrel (1988) was followed.

a) Birds received no feed for the previous 24 hours and water was removed 2 hours before intramuscular injection of isotope.
b) Tritiated water (8 - 10 μCi/kg live-weight) was injected into the breast muscle. Live weight of the bird recorded.
c) After 3 hours without food or water 4 - 5ml of blood was collected by vein puncture in the wing.

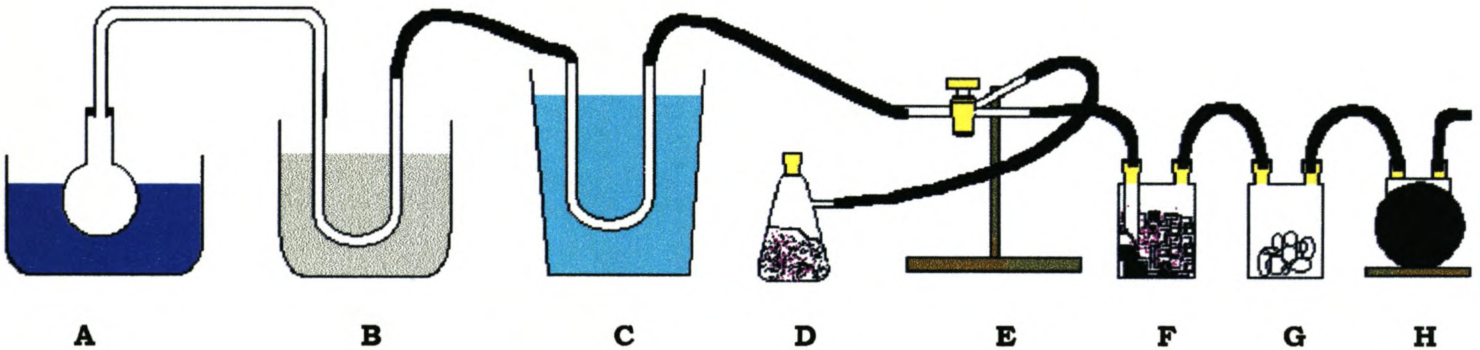
Disposable plastic syringes (5 ml) fitted with 21 gauge, 19 mm needles were used for injection of isotopes. Syringes were weighed before and after isotope injection and the amount injected was determined by difference. Blood samples were placed in vials containing heparin and stored at 4 °C before analysis. Blood samples were also taken from the same birds one week prior to the injection of tritiated water to determine the blank radioactivity of blood.

2.3 RECOVERY OF ISOTOPE FROM BLOOD:

Tritiated water was recovered from the blood by vacuum distillation in an apparatus as shown in Plate 1. Blood samples were placed in a dry Erlenmeyer flask in a water bath at 30 °C and the water vapor was condensed in a U-tube submerged in liquid nitrogen (-196 °C). After all moisture had been recovered from the blood, the vacuum was broken and the contents of the U–tube thawed for radioactivity measurements.

Specific radioactivity was determined on 1 ml weighed samples in glass scintillation vials after mixing with 10 ml scintillation liquid. The 1 ml water sample was weighed to increase the accuracy of the determination of the activity. Standards were prepared from the original stock solution of tritiated water which was injected into the birds. Samples of distilled water and blood distillate from

PLATE 1.



A –	**Erlenmeyer flask in water bath**
B –	**U – tube in liquid nitrogen**
C –	**Bucket with ice**
D –	**Erlenmeyer flask with copper sulphate crystals**
E –	**3 – way valve**
F –	**Container with copper sulphate crystals**
G –	**Container with absorbing paper**
H -	**Vacuum pump**

control birds were used for background counts. Counts were performed for a period of 20 minutes.

The following glass scintillation vials were, therefore, prepared every 8 to 9 weeks:

a) 5 x 1ml $^{1}/_{250}$ dilution of tritiated water

b) 5 x 1ml distilled water used

c) 5 x 1ml blood distillate of normal blood

d) n x 1ml active blood distillate, where n represent the number of birds

Tritium space was calculated as:

$$= \frac{(c - d) \times 250 \times e \text{ ml}}{(b - a)}$$

$$= \frac{(c - d) \times 250 \times e \text{ kg}}{(b - a) \times 1000}$$

where:

- Tritium space = the estimated amount of total body water (kg)
- a = the activity of blood from control birds, no tritium injected
- b = the activity of "active" blood
- c = the activity of a 250 ml stock solution
- d = the activity of the scintillation liquid or 1ml distilled water
- e = volume tritiated water injected into birds

2.4 SLAUGHTER AND CARCASS ANALYSIS PROCEDURE:

At the end of the production period (61 weeks of age) the relationship between actual body moisture and tritium space was estimated. Birds were individually weighed and killed with chloroform. The feathers were removed and the carcasses sealed in plastic bags and stored at -10 °C. Whole frozen birds were chopped into sections in the frozen state and minced in a Wolfking meat grinder using a master die of 3 mm. The mince was mixed and grinded three times to give a fine and uniform material before triplicate samples were taken for determination dry matter (moisture), lipid and crude protein content.

3. RESULTS AND DISCUSSION:

3.1 RELATIONSHIP BETWEEN TRITIUM AND BODY COMPOSITION

The waterspace calculated by the tritiated water and the actual moisture content of the carcass determined by chemical analyses is shown in Table 18 for the different treatments. It appears as if the tritium method generally overestimated the water content of the birds, from 2,61 to 7,41 %. This is in agreement with the work of

TABLE 18 : **Moisture content (% of live body weight) of the broiler breeders, at 61 weeks of age, by using actual chemical analysis (CA) or by tritiated water (TW).**

Treatment	Moisture (CA)	Waterspace (TW)	Difference (%)
1	57,57	60,18	+ 2,61
2	58,76	65,37	+ 6,61
3	59,01	63,61	+ 4,60
4	59,45	61,70	+ 2,25
5	60,78	68,19	+ 7,41
6	60,69	64,81	+ 4,12
7	60,26	65,54	+ 5,28
8	60,47	64,99	+ 4,32

Johnson & Farrell (1988) who found an overestimation of total body water of 10,4 % also using tritiated water in breeders. The magnitude of the overestimation was less than found previously for broiler chickens (Farrell, 1974) and medium-hybrid laying hens (Farrell & Balnave, 1977), which was 18 and 15 % respectively. Given the many potential sources of error in the technique it is not surprising that differences occur between studies. These errors can be divided into two categories

1. those which occur in the direct measurement of total body water,
2. those which occur due to the use of isotopes.

Potential errors in the direct measurement of total body water include loss of carcass water during mincing, sampling errors and weighing and desiccation errors. Other reasons that have been suggested for the inability of tritiated water to estimate precisely are related to the injected dose of tritium water, pipetting and the counting of the sample. Differences in gut fill and water in the intestinal tract of animals can cause differences in the actual water content of animals with similar live weights.

A source of error associated directly with the use of isotopes are insufficient equilibrium time after injection. The vacuum sublimation technique used to obtain a representative water sample from blood was identified, in previous work, as the major factor contributing to the overestimation of total body water (Johnson & Farrell, 1988). These workers concluded that incomplete recovery of isotope in vitro accounted for 70 - 80 % of the observed overestimation in vivo. The remaining 20 - 30 % is probably due to a combination of factors of which urinary loss of injected isotope could account for the majority of the remainder. In radioactivity injected per unit of live weight can influence the magnitude of the over-estimation of waterspace by tritiated water.

A highly significant ($P < 0,01$) relationship between tritiated water and moisture content was found in this work and is illustrated in Fig 44. This illustrates that the indirect method of tritiated water also provides an accurate prediction of the water content of the carcass in this study.

The regression equation is:

Carcass moisture (g) = 162 + (0,862 x g Waterspace)

with standard deviation = 104,2, $R^2 = 0,76$ and $P < 0,01$.

The highly significant negative correlation between body water and body fat has been shown to exist in many animals and birds (Du Preez et al., 1969; Farrell & Balnave, 1977; Gous, 1972 and Johnson & Farrell, 1988). It would appear therefore that a very accurate estimation of carcass fat content can be made of carcasses whose water content is known. As the water content of a bird is relatively easy to measure, this relationship would appear to be very useful in carcass composition studies. In the present study a clear negative relationship was also found between

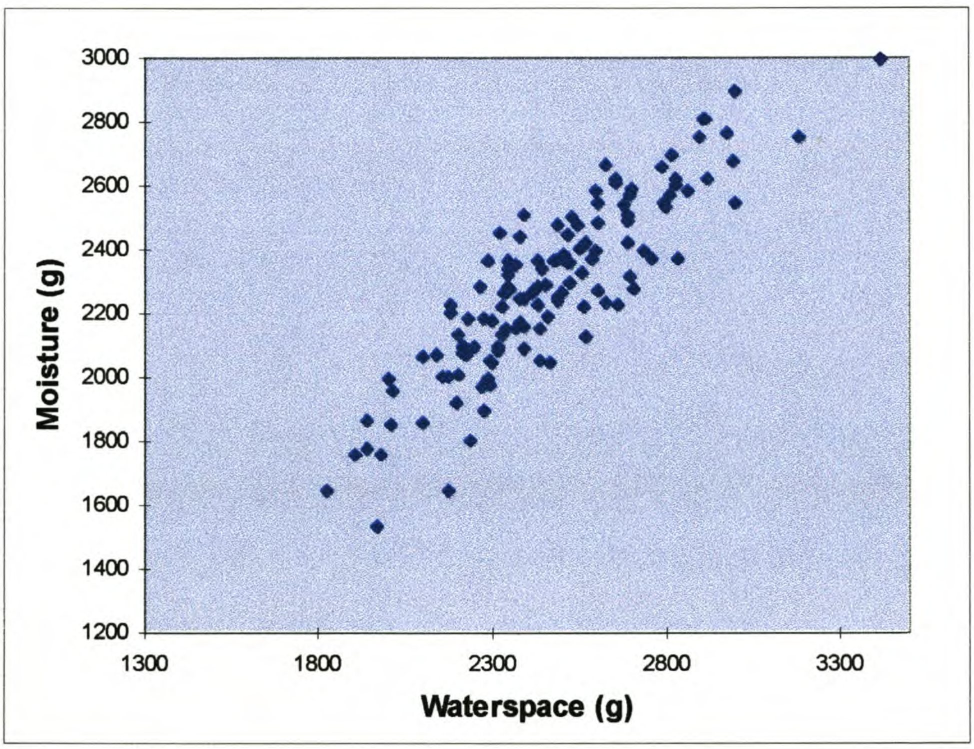


FIGURE 44 : The correlation between body water (y, g moisture in carcass) determined by chemical analysis and tritiated water (x, g waterspace in carcass) in 124 hens (y = 162 + 0,862 x, Standard deviation = 104,2, R^2 = 0,76).

(see addendum 37 for statistical analysis)

moisture and fat. The relationship is illustrated in Fig. 45. The regression equation is:

Fat % = 86,6 – (1,14 x Carcass moisture %)

with standard deviation = 3,246, R^2 = 0,78 and P < 0,01.

Significant correlations between moisture and waterspace and between moisture and fat, as well as between waterspace and protein make it possible to determine carcass composition of broiler breeder females over time. The relationship for the latter correlation between waterspace and protein shown in Fig. 46 was the following:

Protein % = 9,55 + (0,117 x Waterspace %)

with standard deviation = 0,92, R^2 = 0,35 and P < 0,01.

From the carcass analyses data the following regression equation as illustrated in Fig. 47 between waterspace and fat was found:

Fat % = 49,1 – (0,471 x Waterspace %)

with standard deviation = 3,36, R^2 = 0,46 and P < 0,01.

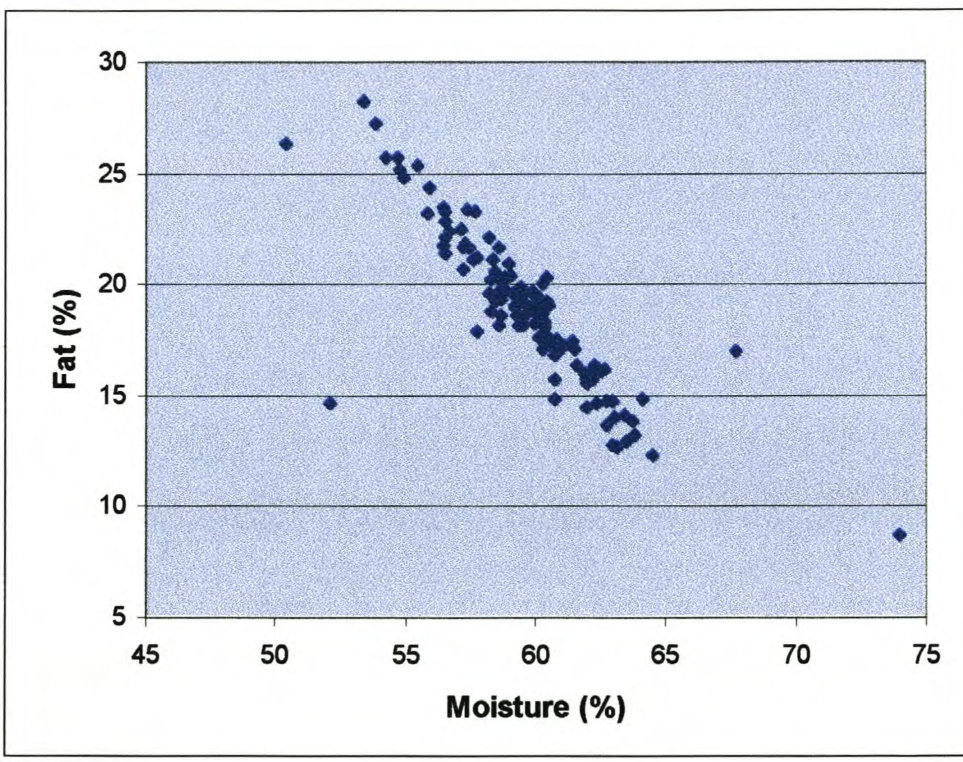


FIGURE 45 : The negative correlation of the moisture (y,%) and fat (x,%) values obtained by chemical analyses of broiler breeders in 124 hens ($y = 86{,}6 - 1{,}14x$, Standard deviation = 3,25, $R^2 = 0{,}78$).

(see addendum 38 for statistical analysis)

These foregoing regression equations were then used to calculate energy and amino acid requirements in an attempt to explain production results that were obtained of the breeders on the different diets. The relationship between the actual determined fat content (g) and the predicted fat content (g) of the carcass by employing the regression equation Fat % = 49,1 – (0,471 x Waterspace %) is illustrated in Fig. 48. This close relationship can indeed be regarded as confirmation that the tritiated water is an accurate indirect method for predicting carcass fat and carcass protein content "in vivo".

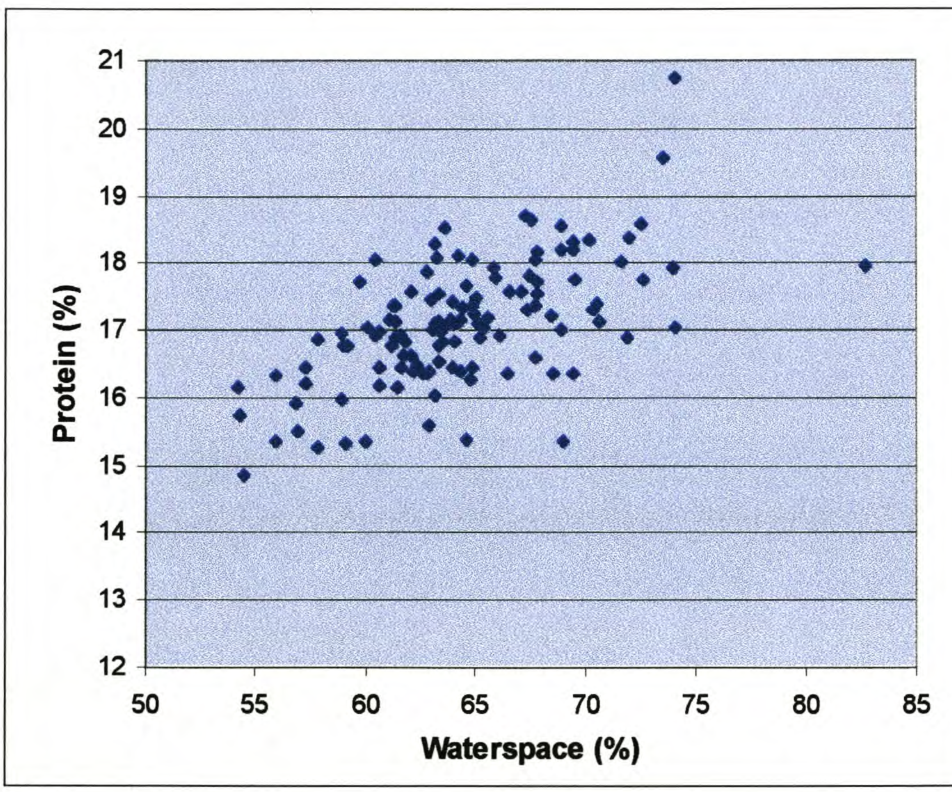


FIGURE 46: The correlation between the protein content of the carcass (y, %) and the amount of tritiated water (x, %) (y = 9,55 + 0,117 x, Standard deviation = 0,92, R^2 = 0,35).

(see addendum 39 for statistical analysis)

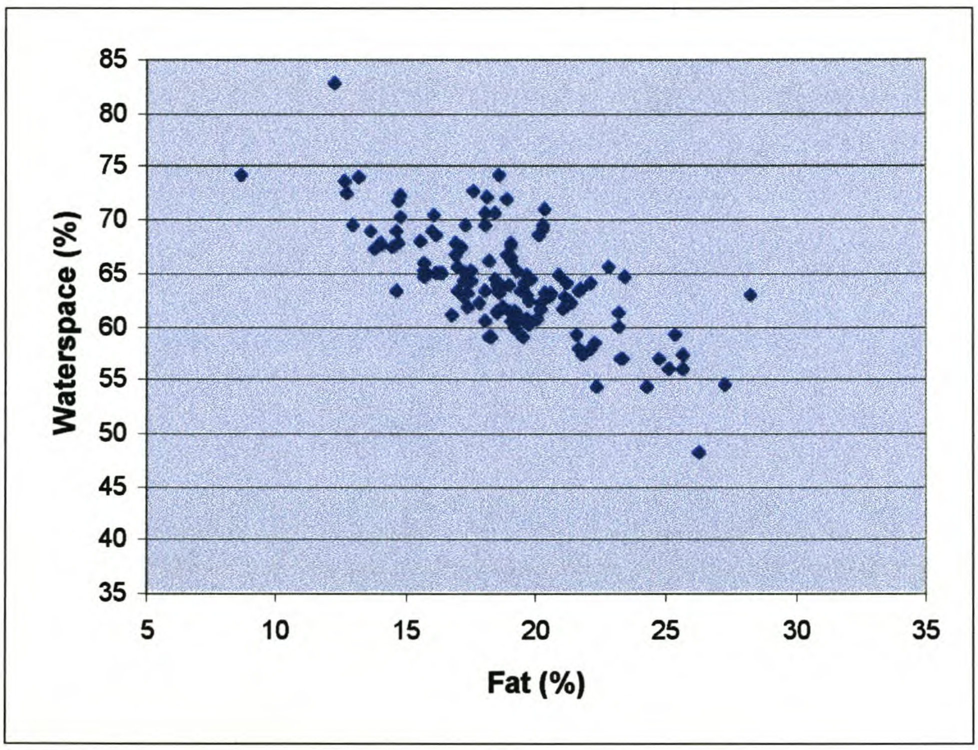


FIGURE 47: **The correlation between the fat content (y, %) of the carcass and the amount of tritiated water (x, %) (y = 49,1 – 0,471 x, Standard deviation = 3,36, R^2 = 0,46).**

(see addendum 40 for statistical analysis)

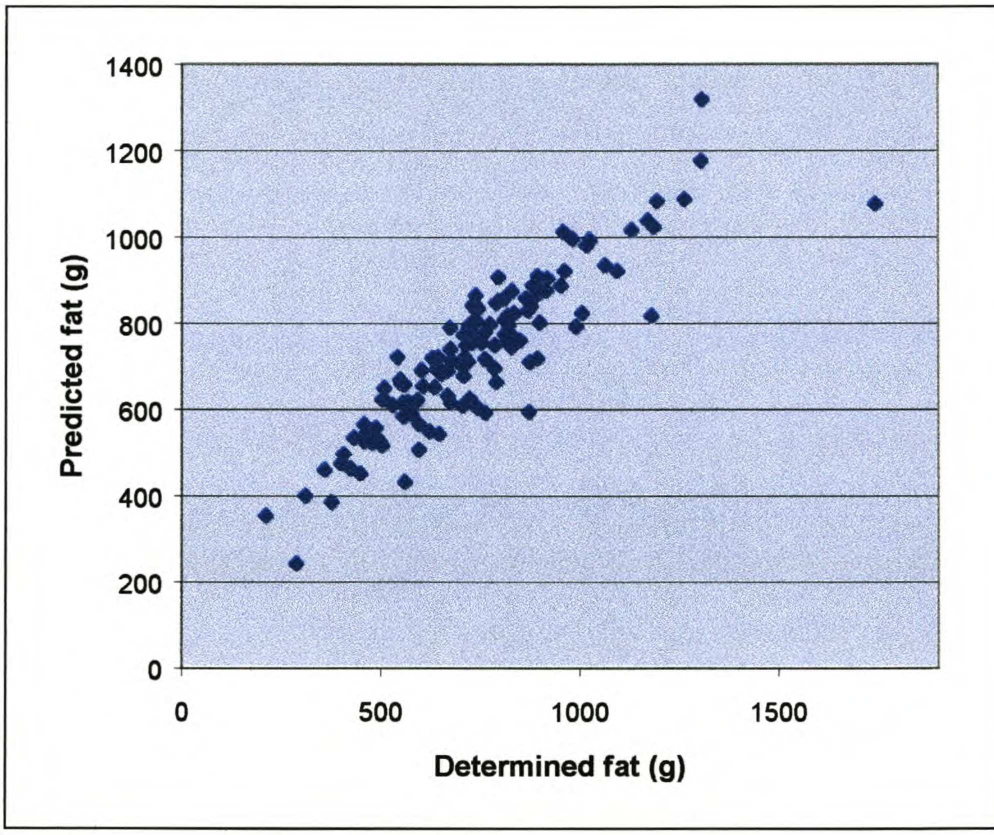


FIGURE 48: The correlation between the determined fat content (y, g) and the predicted fat (x, g) of the carcass of the broiler breeder hens.

(y = 246 + 0,657 x, Standard deviation = 27,3, R^2 = 0,72)

(see addendum 41 for statistical analysis)

3.2 ESTIMATION OF ENERGY REQUIREMENTS FROM BODY COMPOSITION DATA

Energy requirements for the breeders at various stages during the production cycle were calculated either according to the Effective Energy (EE) system of Emmans (1994) or the conventional ME system. This was done from estimated body composition data at 26, 35, 43, 52 and 61 weeks of age taking into account maintenance needs, protein growth, lipid growth and egg output:

Requirements according to the Emmans System

- EE for maintenance (EE_m) was calculated using the equation of Emmans (1994) as:

  $EE_m = (1{,}63/P_m^{\ 0{,}27}) \ . \ P$ (MJ/day)

  Where :

  P_m = mature weight (kg), taken as 0,706 kg for all treatments (0,706 kg was calculated using the mature hen weight of 4,143 kg of the experiment multiplied by the average protein content of 17,06 % at 61 weeks of age).

  P = protein weight (kg)

- The EE requirements for protein and lipid gains (EE_g) were calculated as:

  $EE_g = 50 \ PR + 56 \ LR$ (MJ/day) (Emmans, 1994)

  Where :

  PR = protein retention (kg/day)

  LR = lipid retention (kg/day)

- The EE requirement for eggs (EE_e) was calculated as :

  $EE_e = 10 . EO / 1000$ (MJ/day)

  Where :

  EO = egg output (g/day)

  And the value of 10 comes from Table 2.4 of Emmans & Fisher (1986).

- Loss of body heat predicted by formula presented by Rose (1997).

  $(a - bT) \times W^{0,75}$

  Where :

  a and b are constants that relate to the degree of insulation of the bird. The values a = 0,21 and b = 0,0082 were termed good values by the author for well-feathered growing or laying chickens.

  W = body weight (kg)

  T = effective ambient temperature (°C). The daily average effective ambient temperature was calculated for the same period as when tritiated water data was collected. The average temperature were 17,54 °C for week 21 - 26; 14,6 °C for week 27 - 35; 14,6 °C for week 36 - 43; 19,42 °C for week 44 - 52 and 22,04 °C for week 53 to 61.

Requirements according to the ME system

In the second approach conventional ME_n values were used to estimate total energy requirements for maintenance, body heat loss, weight gain and egg production.

The following formulas as suggested by Rose (1997) were used:

- Maintenance = $0{,}35W^{0{,}75}$

  Loss of body heat = $(a - bT) \times W^{0{,}75}$

  Where

  a and b are constants that relate to the degree of insulation of the bird. The values a = 0,21 and b = 0,0082 were termed "good values" by the author for well-feathered growing or laying chickens.

  W = body weight (kg)

  T = effective ambient temperature (°C)

- ME for growth = 10G x 0,6

  ME for egg mass output = 25Y + 3,6A + 1,25S

  Where

  G = weight gain (kg)

  0,6 = lean growth percentage

  Y = weight of yolk produced (kg), a value of 32 % of egg mass is used

  A = weight of albumen produced (kg), a value of 56 % of egg mass is used

  S = weight of shell produced (kg), a value of 12 % of egg mass is used

3.3 ENERGY INTAKE OF THE BREEDERS

The metabolizable values of the diets were converted to EE according to the formula given by Emmans (1994).

- The Effective Energy content of the diets were calculated using the equation:

  EE = 1,17 ME – 4,2 CP – 2,44

  where :

  ME = 12,5 kJ/g for all diets

  CP = crude protein content g/g.

- The EE Intakes (EEI) were calculated as :

EEI	=	Food allowance	x	EEC
(kJ/d)		(g/d)		(kJ/g)

Although all the treatments consumed a diet containing a metabolizable energy level of 12,5 MJ/kg, the effective energy between the treatments declined as the protein level increased. The effective energy of the diets with the lower protein content was 0,24 MJ/kg higher than the diets with the higher protein level in the feed. This is equivalent to 38,4 kJ/day effective energy for a bird consuming 160 g/day. The daily effective energy intake of 1866 kJ EE and 1672 kJ EE energy during peak production is equal to 2000 kJ and 1800 kJ metabolizable energy respectively.

3.4 CALCULATION OF EXCESS ENERGY CONSUMED

The calculated effective energy requirements and effective energy intakes for the different treatments are given in Table 19. In Table 20 the results for metabolizable energy values are given.

The regression equation of the correlation between protein and waterspace (Protein % = 9,55 + 0,117 x Waterspace %) was used to establish the protein content of the carcass to then calculate energy requirement for maintenance and protein weight gain. This value was then subtracted together with the energy requirement for egg output and heat loss from the energy intake value to determine the calculated excess energy consumed.

The daily body fat gains for each period was obtained by taking into consideration the fat content of the previous period. The period 21 to 26 weeks of age was used as the baseline. The energy required to deposit 1 g of fat was taken as 56 kJ and where there was a fat loss in a period the energy yield was taken as 39,6 kJ/g (Emmans, 1994).

From Table 19 it appeared that, at the lowest levels of protein intake, the energy consumed in excess of requirements closely resembled the amount of energy deposited as fat. Difference amounted to between 10 and 75 kJ/day. These

Table 19: **Effective energy consumption and expenditure by the broiler breeder females.**

Treatment Daily nutrient intake		Time period (weeks)	Feed Intake (g/day)	ME content of feed (MJkg) *a	EE content of feed (MJ/kg) *b	Waterspace as % of body weight *c	Body protein as derived from water-space (%) *d	Average hen weight at end of period (kg)	EE for maintenance (kJ/day)	Egg output (g/h/day)	Body Weight gain (g / day)
2000 kJ ME	900 mg Lys	21–26	131.6	12.5	11.664	69.91	17.73	3.096	987.31	6.21	20.98
		27–35	160	12.5	11.664	64.54	17.10	3.453	1057.66	44.3	4.83
		36-43	160	12.5	11.664	62.43	16.85	3.727	1123.14	45.1	4.79
		44-52	157.7	12.5	11.664	62.08	16.81	3.953	1188	40.81	3.81
		53-61	151	12.5	11.664	60.18	16.59	4.093	1211.83	35.36	2.12
	1050 mg Lys	21–26	131.6	12.5	11.584	69.5	17.68	3.126	993.87	6.2	22.19
		27–35	160	12.5	11.584	66.31	17.31	3.47	1077.27	45.2	5.32
		36-43	160	12.5	11.584	63.85	17.02	3.682	1121.84	47.49	3.64
		44-52	157.7	12.5	11.584	65.54	17.22	3.846	1187.06	40.46	2.68
		53-61	151	12.5	11.584	65.37	16.96	3.943	1215.42	36.39	2.73
	1200 mg Lys	21–26	131.6	12.5	11.504	73.5	18.15	3.273	1071.32	7.16	24.67
		27–35	160	12.5	11.504	67.8	17.48	3.589	1126.76	45.16	4.81
		36-43	160	12.5	11.504	63.92	17.03	3.815	1162.99	46.82	4.07
		44-52	157.7	12.5	11.504	63.8	17.01	3.964	1207.3	42.73	2.83
		53-61	151	12.5	11.504	63.61	17.00	4.082	1241.42	34.47	2
	1350 mg Lys	21–26	131.6	12.5	11.423	69.76	17.71	3.226	1027.63	6.17	25.67
		27–35	160	12.5	11.423	67.48	17.45	3.611	1130.96	45.83	6.27
		36-43	160	12.5	11.423	63.46	16.97	3.868	1174.97	49.56	4.57
		44-52	157.7	12.5	11.423	64.26	17.07	3.957	1209.43	42.2	1.54
		53-61	151	12.5	11.423	61.7	16.77	4.143	1241.4	32.99	3.05
1800 kJ ME	900 mg Lys	21–26	123.3	12.5	11.6	72.23	18.00	2.905	942.21	5.16	17.79
		27–35	144.1	12.5	11.6	68.14	17.52	3.202	1007.82	40.22	4.57
		36-43	144	12.5	11.6	64.75	17.13	3.312	1016.1	44.79	1.94
		44-52	141.3	12.5	11.6	65.51	17.21	3.433	1059.34	40.46	1.83
		53-61	136	12.5	11.6	68.19	17.53	3.459	1089.11	34.48	0.48
	1050 mg Lys	21–26	123.3	12.5	11.532	71.84	17.96	2.962	957.99	5.83	19.48
		27–35	144.1	12.5	11.532	67.89	17.49	3.302	1037.36	43.24	5
		36-43	144	12.5	11.532	65.21	17.18	3.468	1067.7	45.4	3.05
		44-52	141.3	12.5	11.532	65.28	17.19	3.598	1108.32	40.25	2
		53-61	136	12.5	11.532	64.81	17.13	3.624	1112.33	36.87	0.44
	1200 mg Lys	21–26	123.3	12.5	11.463	71.33	17.90	3.039	979.25	6.13	22
		27–35	144.1	12.5	11.463	66.65	17.35	3.324	1034.6	44.88	4.33
		36-43	144	12.5	11.463	64.64	17.11	3.444	1055.71	46.08	2.11
		44-52	141.3	12.5	11.463	64.25	17.07	3.567	1090.15	43.36	2
		53-61	136	12.5	11.463	65.54	17.22	3.635	1121.93	37.03	1.06
	1350 mg Lys	21–26	123.3	12.5	11.393	72.06	17.98	2.989	968.26	5.75	20.76
		27–35	144.1	12.5	11.393	67.79	17.48	3.401	1067.66	45.19	5.63
		36-43	144	12.5	11.393	64.03	17.04	3.540	1080.07	46.53	2.46
		44-52	141.3	12.5	11.393	64.42	17.09	3.662	1120.64	43.43	2.1
		53-61	136	12.5	11.393	64.99	17.15	3.848	1182.71	39.03	2.86

*a- ME = Metabolizable energy

*b- EE = Effective energy

*c- Waterspace as % of body weight as determined by tritiated water

*d- Protein calculated from waterspace = 9,55 + 0,117 x Waterspace

Table 19 (continued)

Treatment Daily nutrient intake		EE for eggs (kJ/day)	EE for protein weight gain (kJ/day)	Energy lost as heat (kJ/day) *e	Total calculated EE requirement (kJ/day) *f	Actual EE intake (kJ/day)	EE consumed in excess of requirement (kJ/day)	Body fat according to waterspace values (g) *g	Fat deposited during period (g fat/day) *h	Energy equivalent of deposited fat (kJ/day)
2000 kJ ME	900 mg Lys	62.1	166.81	154	1369	1536	167	500.7		
		443	33.02	229	1760	1866	106	645.8	2.6	129
		451	33.62	242	1850	1866	16	734.1	1.8	88
		408.1	32.56	142	1773	1840	67	785.1	0.91	45
		353.6	11.46	78	1658	1761	103	849.5	1.15	57
	1050 mg Lys	62	185.93	156	1396	1525	129	511.6		
		452	37.99	230	1793	1853	60	620	1.93	96
		474.9	23.3	240	1859	1853	-6	700.6	1.64	81
		404.6	31.71	139	1762	1827	65	701.2	0	1
		363.9	12.63	76	1650	1749	99	722	0.37	52
	1200 mg Lys	71.6	227.83	161	1530	1515	-15	473.9		
		451.6	26.52	235	1835	1841	6	616.1	2.53	126
		468.2	19.81	246	1896	1841	-55	724.6	2.21	109
		427.3	22.16	143	1800	1815	15	755.2	0.55	27
		344.7	15.21	78	1680	1737	57	781.3	0.47	23
	1350 mg Lys	61.7	221.86	159	1469	1504	35	524		
		458.3	46.47	237	1869	1828	-41	625.3	1.81	90
		495.6	23.79	249	1942	1828	-114	743.1	2.4	118
		422	16.80	142	1791	1802	11	745.2	0.04	2
		329.9	15.35	79	1667	1725	58	830.2	1.52	76
1800 kJ ME	900mg Lys	51.6	157.75	147	1297	1431	134	438.1		
		402.2	30.27	216	1652	1672	20	544.5	1.9	95
		447.9	5.48	222	1689	1670	-19	616.1	1.46	72
		404.6	21.23	128	1612	1639	27	626.3	0.18	9
		344.8	12.16	69	1513	1578	65	587.4	-0.69	25
	1050 mg Lys	58.3	168.57	149	1332	1422	90	452.1		
		432.4	36.34	221	1723	1662	-61	565.4	2.02	101
		454	16.22	229	1766	1661	-105	637.6	1.47	72
		402.5	20.20	133	1663	1630	-33	660.3	0.41	20
		368.7	1.97	71	1553	1568	15	673.1	0.23	11
	1200 mg Lys	61.3	176.22	152	1368	1414	46	471.2		
		448.8	26.03	222	1728	1652	-76	588.6	2.1	104
		460.8	11.36	228	1755	1651	-104	642.5	1.1	54
		433.6	17.34	132	1673	1620	-53	671.9	0.53	26
		370.3	13.56	71	1626	1559	-18	662.7	-0.16	6
	1350 mg Lys	57.5	180.18	150	1355	1405	50	453.1		
		451.9	45.31	226	1787	1642	-145	583.9	2.34	116
		465.3	7.79	233	1785	1641	-144	670.5	1.77	87
		434.3	20.06	134	1709	1610	-100	686.9	0.29	15
		390.3	27.26	75	1676	1549	-125	711.5	0.44	22

*e - Heat (kJ / day) = (a - bTemperature) x $W^{0.75}$

*g- Fat calculated from waterspace = 49.1 - 0.471(%waterspace)

*f - Total EE requirement (kJ/day) = EE maintenance + EE eggs + EE protein weight gain + Heat energy

*h - Fat gained during period (g) minus predicted fat previous period / days in current period

Table 20: **Metabolizable energy consumption and expenditure by the broiler breeders.**

Treatment Daily nutrient intake		Time period (weeks)	Feed Intake (g/day)	ME content of feed (MJkg) *a	Waterspace as % of body weight *b	Body protein as derived from water-space (%) *c	Average hen weight at end of period (kg)	ME maintenance (kJ/kg)	ME egg output (kJ/day)	ME weight gain (kJ/day)
2000 kJME	900 mg Lys	21–26	131.6	12.5	69.91	17.73	3.096	816.9	63.1	126
		27–35	160	12.5	64.54	17.10	3.453	886.6	450.4	29
		36-43	160	12.5	62.43	16.85	3.727	938.8	458.5	29
		44-52	157.7	12.5	62.08	16.81	3.953	981.2	414.9	23
		53-61	151	12.5	60.18	16.59	4.093	1007.2	359.5	13
	1050 mg Lys	21–26	131.6	12.5	69.5	17.68	3.126	822.8	63	133
		27–35	160	12.5	66.31	17.31	3.47	889.8	459.5	32
		36-43	160	12.5	63.85	17.02	3.682	930.3	482,8	22
		44-52	157.7	12.5	65.54	17.22	3.846	961.2	411.3	16
		53-61	151	12.5	65.37	16.96	3.943	979.4	369.9	16
	1200 mg Lys	21–26	131.6	12.5	73.5	18.15	3.273	851.7	72.8	148
		27–35	160	12.5	67.8	17.48	3.589	912.6	459.1	29
		36-43	160	12.5	63.92	17.03	3.815	955.4	475.9	24
		44-52	157.7	12.5	63.8	17.01	3.964	983.3	434.4	17
		53-61	151	12.5	63.61	17.00	4.082	1005.1	350.4	12
	1350 mg Lys	21–26	131.6	12.5	69.76	17.71	3.226	842.5	62.7	154
		27–35	160	12.5	67.48	17.45	3.611	916.8	465.9	38
		36-43	160	12.5	63.46	16.97	3.868	965.3	503.8	27
		44-52	157.7	12.5	64.26	17.07	3.957	981.9	429	9
		53-61	151	12.5	61.7	16.77	4.143	1016.4	335.4	18
1800 kJ ME	900 mg Lys	21–26	123.3	12.5	72.23	18.00	2.905	778.8	52.3	107
		27–35	144.1	12.5	68.14	17.52	3.202	837.8	439.6	27
		36-43	144	12.5	64.75	17.13	3.312	859.3	461.5	12
		44-52	141.3	12.5	65.51	17.21	3.433	882.7	409.2	11
		53-61	136	12.5	68.19	17.53	3.459	887.7	374.8	3
	1050 mg Lys	21–26	123.3	12.5	71.84	17.96	2.962	790.2	59.3	117
		27–35	144.1	12.5	67.89	17.49	3.302	857.3	439.6	30
		36-43	144	12.5	65.21	17.18	3.468	889.5	461.5	18
		44-52	141.3	12.5	65.28	17.19	3.598	914.4	409.2	12
		53-61	136	12.5	64.81	17.13	3.624	919.3	374.8	3
	1200 mg Lys	21–26	123.3	12.5	71.33	17.90	3.039	805.6	62.3	132
		27–35	144.1	12.5	66.65	17.35	3.324	861.6	456.3	26
		36-43	144	12.5	64.64	17.11	3.444	884.8	468.4	13
		44-52	141.3	12.5	64.25	17.07	3.567	908.4	440.8	12
		53-61	136	12.5	65.54	17.22	3.635	921.4	376.4	6
	1350 mg Lys	21–26	123.3	12.5	72.06	17.98	2.989	795.6	58.5	125
		27–35	144.1	12.5	67.79	17.48	3.401	876.5	459.4	34
		36-43	144	12.5	64.03	17.04	3.540	903.3	473	15
		44-52	141.3	12.5	64.42	17.09	3.662	926.5	441.5	13
		53-61	136	12.5	64.99	17.15	3.848	961.6	396.8	17

*a – ME = Metabolizable Energy　　*b – Waterspace as % of body weight as determined by tritiated water

*c – Protein derived from waterspace = 9.55 + 0.117 (Waterspace)　　*d - ME loss of body heat (kJ/day) = (a-bT) x $W^{0.75}$

Table 20 (continued)

Treatment Daily nutrient intake		Time period (weeks)	ME for loss of body heat (kJ/day)	Total calculated ME requirement (kJ/day) *e	Actual ME intake (kJ/day)	Excess ME consumed (kJ/day)	Body fat according to waterspace values (g) *f	Fat deposited during period (g fat/day *g	Energy equivalent of deposited fat (kJ/day)
2000 kJ ME	900 mg Lys	21–26	154	1160	1646	485	500.7		
		27–35	229	1595	2000	405	645.8	2.6	129
		36--43	242	1668	2000	332	734.1	1.8	88
		44--52	140	1558	1972	413	785.1	0.91	45
		53--61	84	1464	1888	424	849.5	1.15	57
	1050 mg Lys	21–26	156	1175	1646	471	511.6		
		27–35	230	1611	2000	389	620	1.93	96
		36--43	240	1675	2000	325	700.6	1.64	81
		44--52	137	1525	1972	447	701.2	0	1
		53--61	82	1448	1888	440	722	0.37	52
	1200 mg Lys	21–26	161	1234	1646	412	473.9		
		27–35	235	1636	2000	364	616.1	2.53	126
		36--43	246	1702	2000	298	724.6	2.21	109
		44--52	140	1574	1972	397	755.2	0.55	27
		53--61	84	1452	1888	436	781.3	0.47	23
	1350 mg Lys	21–26	159	1219	1646	427	524		
		27–35	237	1657	2000	343	625.3	1.81	90
		36--43	249	1746	2000	254	743.1	2.4	118
		44--52	140	1560	1972	412	745.2	0.04	2
		53--61	85	1455	1888	432	830.2	1.52	76
1800 kJ ME	900 mg Lys	21–26	147	1085	1542	456	438.1		
		27–35	216	1490	1801	311	544.5	1.9	95
		36--43	222	1548	1800	252	616.1	1.46	72
		44--52	126	1431	1766	336	626.3	0.18	9
		53--61	74	1315	1700	385	587.4	-0.69	25
	1050 mg Lys	21–26	149	1116	1542	426	452.1		
		27–35	221	1548	1801	253	565.4	2.02	101
		36--43	229	1599	1800	201	637.6	1.47	72
		44--52	130	1466	1766	301	660.3	0.41	20
		53--61	77	1374	1700	326	673.1	0.23	11
	1200 mg Lys	21–26	152	1152	1542	389	471.2		
		27–35	222	1566	1801	235	588.6	2.1	104
		36--43	228	1594	1800	206	642.5	1.1	54
		44--52	129	1490	1766	276	671.9	0.53	26
		53--61	77	1381	1700	319	662.7	-0.16	6
	1350 mg Lys	21–26	150	1129	1542	413	453.1		
		27–35	226	1596	1801	205	583.9	2.34	116
		36--43	233	1624	1800	176	670.5	1.77	87
		44--52	132	1512	1766	254	686.9	0.29	15
		53--61	80	1456	1700	244	711.5	0.44	22

*e - Total EE requirement (kJ/day) = EE maintenance + EE eggs + EE protein weight gain   *f - Fat derived from waterspace = 49.1 - 0.471(%waterspac

*g - Predicted fat(f) minus predicted fat previous period / days in current period differences are relatively small taking into consideration that a change of only 1 °C in the environmental temperature has an effect of ±20 kJ/day on the amount of energy required.

The amount of effective energy excess of requirements during the different periods is shown in Fig. 49 and in Fig. 50 for the diets supplying 2000 and 1800 kJ/day respectively. The excess energy consumed was lower in the treatments that consumed the higher amino acid levels. In Tables 19 and 20 this is explained by the fact that more energy was required for maintenance and weight gain. In Chapter 2 the results showed that the higher protein (amino acid) level significantly increased the body weight of the breeders (Table 15). The treatments receiving the lower energy levels appear not to have sufficient energy intake according to the calculated effective energy (Table 19).

According to the calculated metabolizable energy intake there appears to be sufficient energy intakes at every treatment (Table 20). At the higher energy intakes the excess energy was between 254 and 485 ME/day and at the lower energy intake the excess energy was between 176 and 456 ME/day. The maximum requirement was calculated to be 1746 kJ ME/day. The maximum requirement according to the effective energy method was 1942 kJ EE/day and in both methods (EE and ME) this was for the period 36 to 43 weeks. The reason for the difference in excess energy calculated by the two methods is mainly due to the difference in approach of calculating energy required for maintenance. The calculated

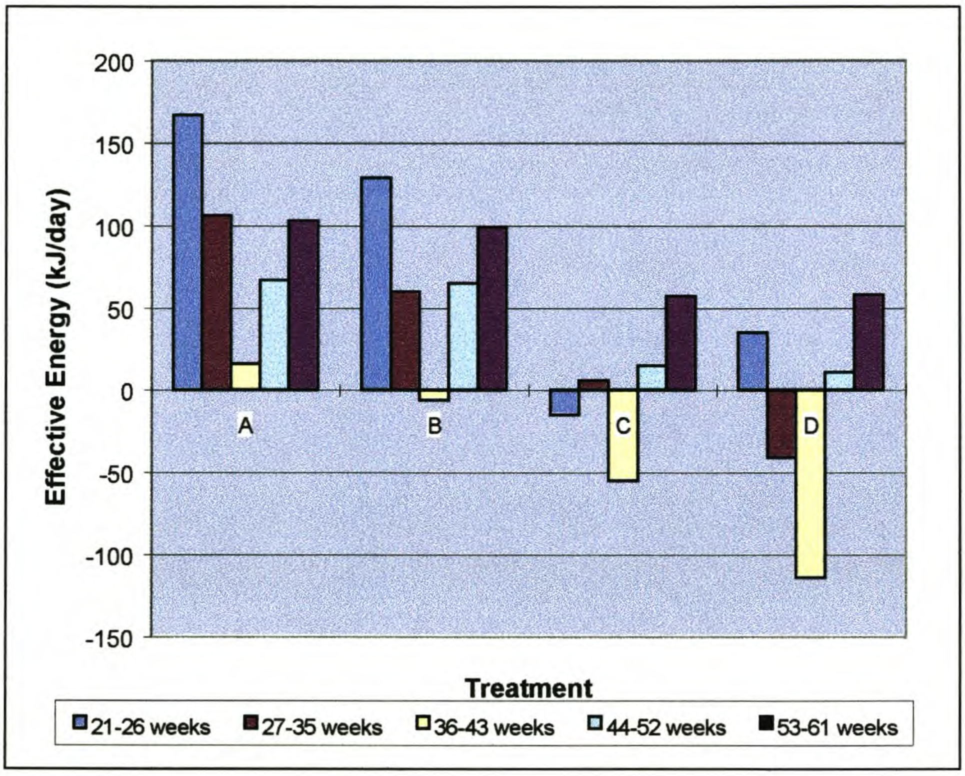


FIGURE 49: The calculated excess Effective Energy consumed (kJ/day) by breeders receiving 2000 kJ/day energy and where A = 900 mg lys/day; B = 1050 mg lys/day; C = 1200 mg lys/day and D = 1350 mg lys/day.

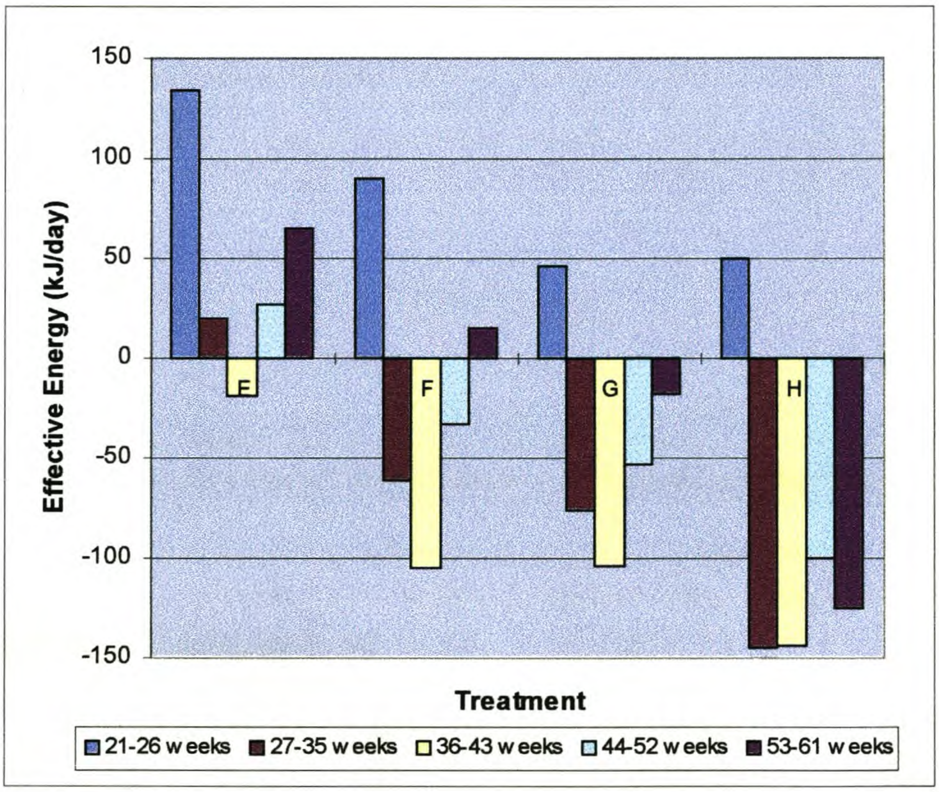


FIGURE 50: The calculated excess Effective Energy consumed (kJ/day) by breeders receiving 1800 kJ/day energy and where E = 900 mg lys/day; F = 1050 mg lys/day; G = 1200 mg lys/day and H = 1350 mg lys/day.

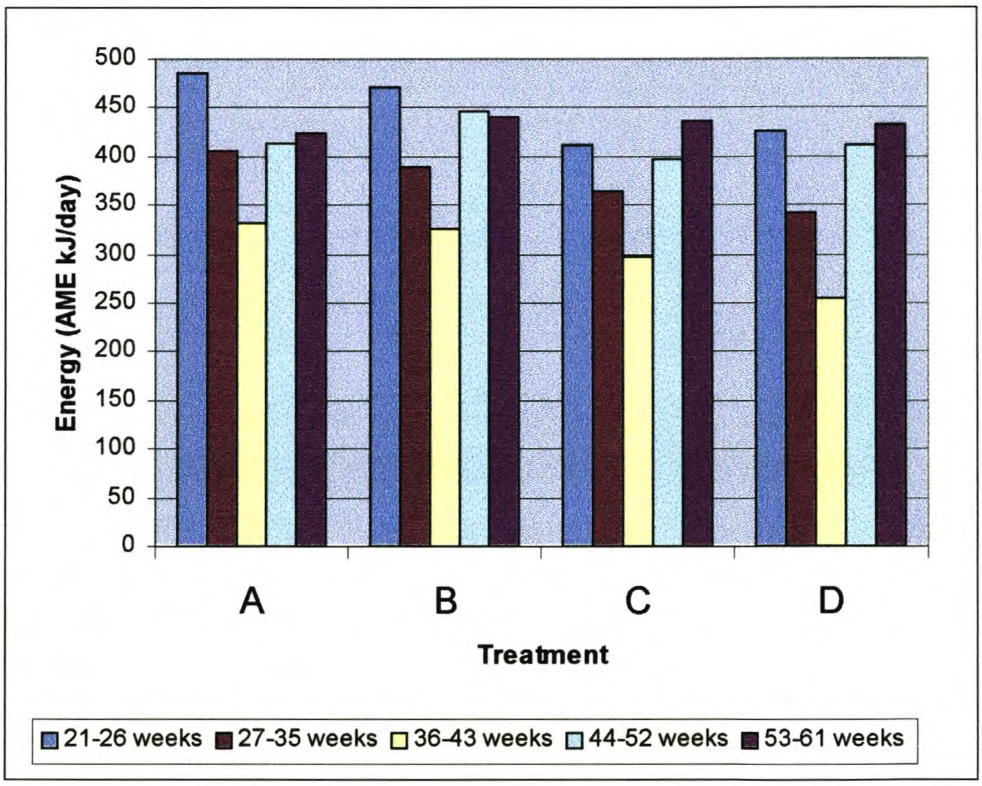


FIGURE 51: The calculated excess Metabolizable Energy consumed (kJ/day) by breeders receiving 2000 kJ/day energy and where A = 900 mg lys/day; B = 1050 mg lys/day; C = 1200 mg lys/day and D = 1350 mg lys/day.

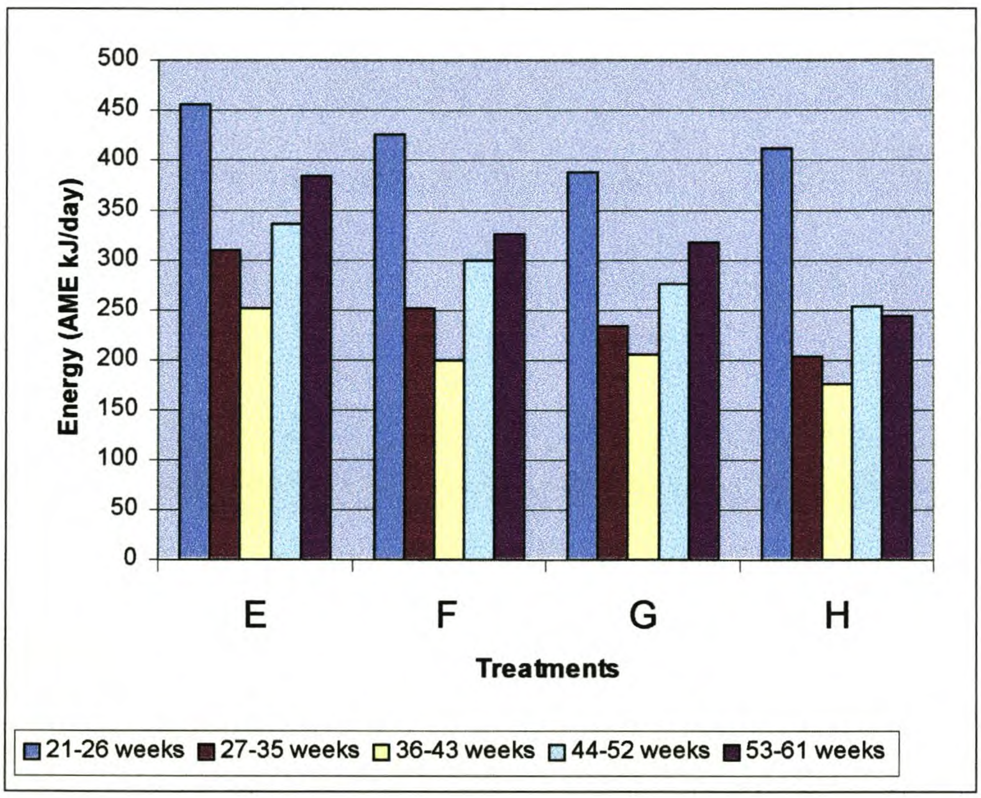


FIGURE 52: The calculated excess Metabolizable Energy consumed (kJ/day) by breeders receiving 1800 kJ/day energy and where E = 900 mg lys/day; F = 1050 mg lys/day; G = 1200 mg lys/day and H = 1350 mg lys/day.

requirements for energy of eggs, weight gain and heat loss was similar for the two methods of calculating energy requirements.

3.5 RELATIONSHIP BETWEEN PRODUCTION AND FAT DEPOSITION

The excess energy deposited as fat was correlated with the production results within the various periods. The excess energy values were altered to correspond with the production periods as given in Chapter 2. The excess energy values of week 27 to 35 was correlated with the first production period (week 23 to 35), excess energy values of week 36 to 52 was correlated with the production period week 36 to 48 and finally the excess energy values for week 53 to 61 was correlated with production results of week 49 to 61. The significant ($P < 0,05$) production responses found in Chapter 2 were correlated with the excess energy during the corresponding periods.

In Fig. 53 this is illustrated with hen day production versus excess energy consumed for the period week 49 to 61. The highly significant ($P < 0,017$) regression equation was y = 56,9 - 0,735 x Excess energy. In Chapter 2 it was shown that the hen day production was significantly reduced by the higher energy intake in the period from week 49 to 61. These results supports the fact that excess energy and over feeding can have a negative effect on production (Robbins et al., 1986; Katonbaf et al., 1989 and Yu et al., 1992). Reducing the energy in the later part of the laying cycle may give improvement in performance when compared to ad libitum fed birds (Blair et al., 1976).

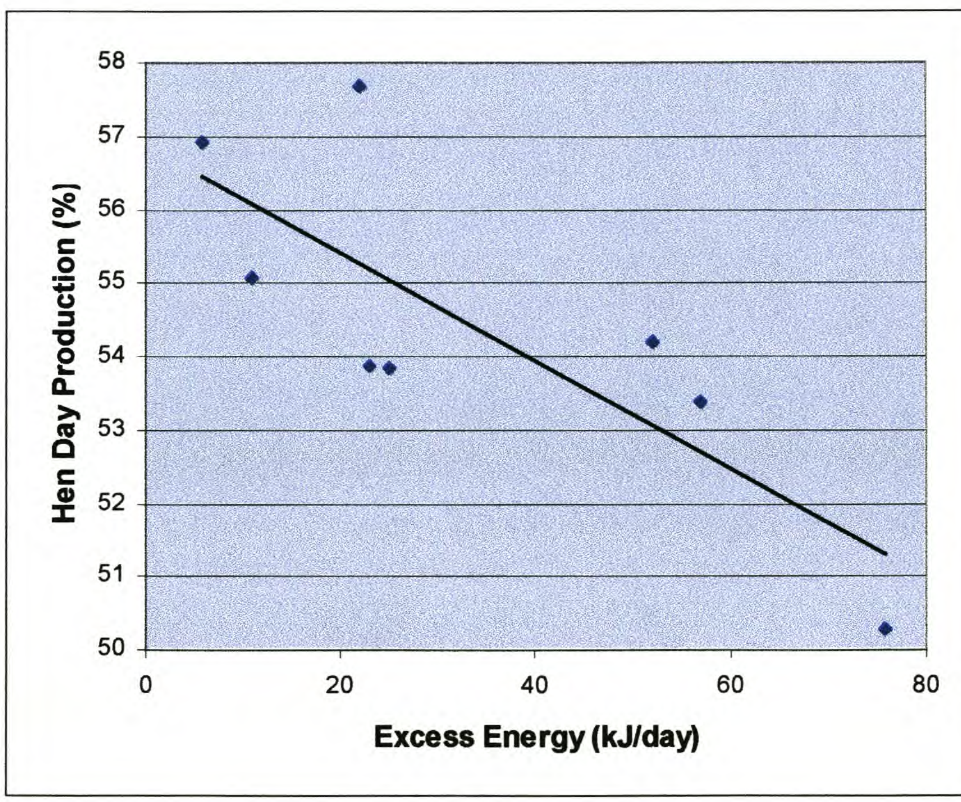


FIGURE 53 : The correlation between the hen day production (y, %) and the excess energy consumed (x, kJ/day) of the broiler breeder hens for the period week 49 to 61 (y = 56,9 - 0, 735 x, Standard deviation = 0,93, R^2 = 0,58).

(see addendum 43 for statistical analysis)

From Table 15 it was also evident that the higher body weight was also significantly increased by the higher energy content of the diet and it is expected that the higher body weights was due to excess energy being deposited as fat. The correlation between the excess energy, as fat deposition, and the weight gain was significant ($P < 0,026$) for the period 36 to 48 weeks (Fig. 54). For the total period this relationship approached significance ($P < 0,057$). These relationships proves that excess energy was used for weight gain. A significant correlation ($P < 0,05$) between fat content and body weight show that the weight gain that took place was mostly in the form of fat deposition, as expected (Fig. 55).

Leeson & Summers (1991) calculated the energy requirements of a commercial broiler breeder strain from 20 - 28 weeks. They suggest that the breeder is in a very precarious situation with regard to energy balance at the critical time of sexual maturity. This could explain the beneficial effect in this experiment, although not significant, on egg production in the first period of production (23 - 35 weeks) of the birds receiving the higher energy diets. In this present study it was also found that for period 22 - 35 weeks of age the calculated effective energy indicated a deficiency at the lower energy intakes and this effect was more noticeable at the higher amino acid intakes (Table 19). This is illustrated in Fig. 49 and 50.

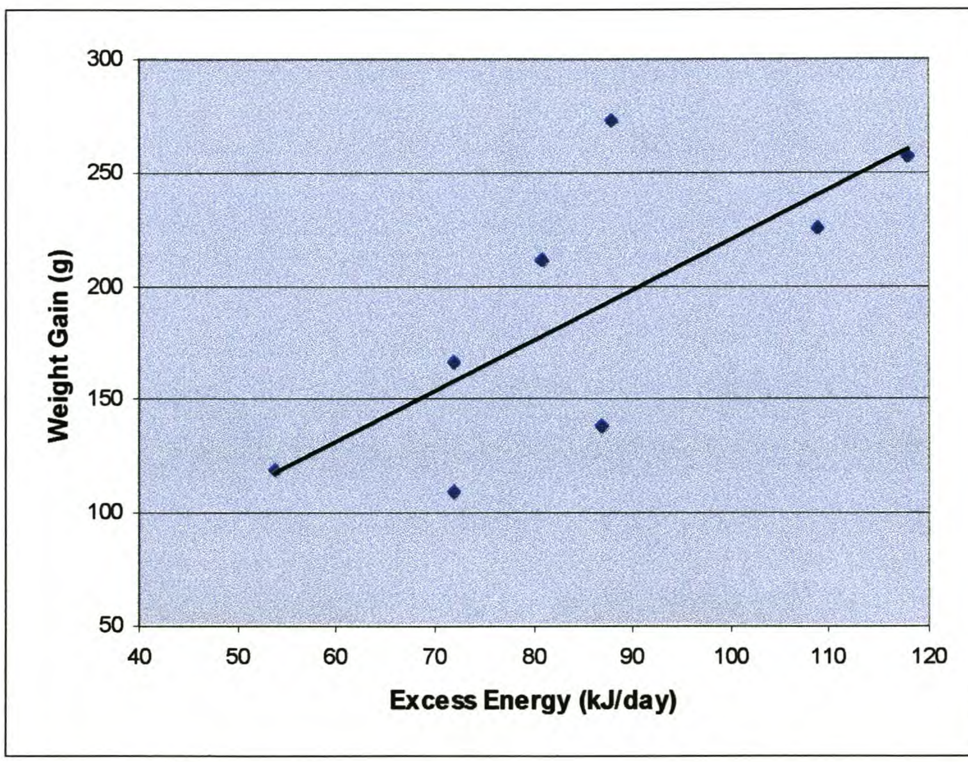


FIGURE 54 : The correlation between the weight gain (y, g) and the excess energy consumed (x, kJ/day) of the broiler breeder hens for the period week 36 to 48 (y = - 21,8 + 4,2 x, Standard deviation = 73, R^2 = 0,52).

(see addendum 44 for statistical analysis)

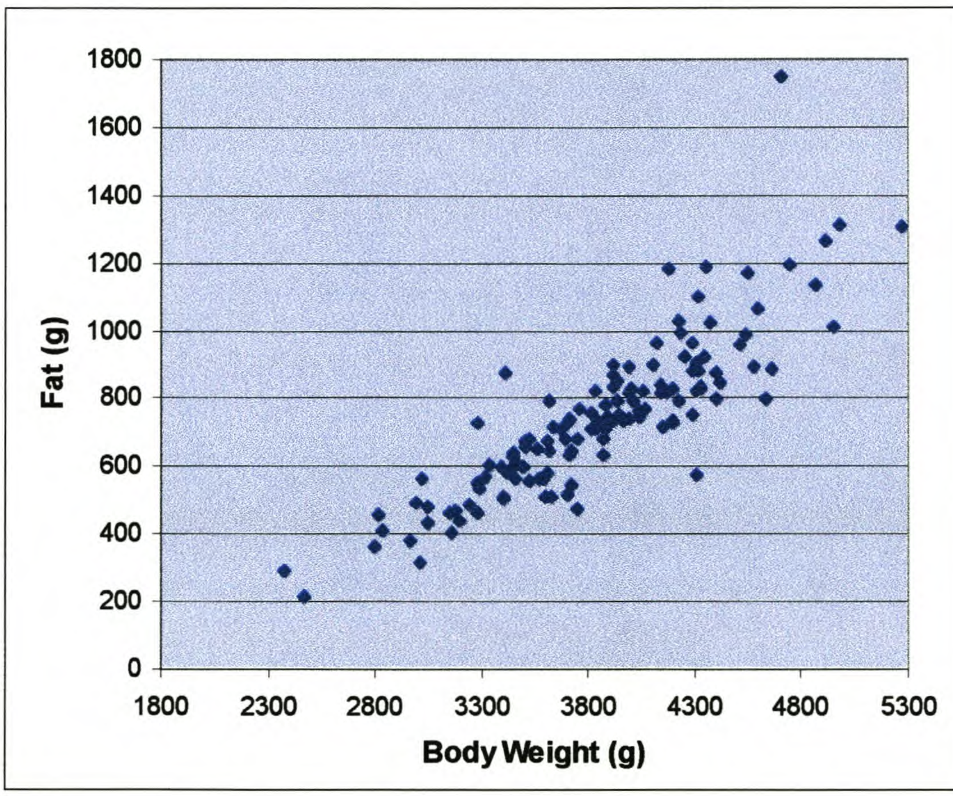


FIGURE 55: The correlation between the fat content (y, g) of the carcass and the body weight (x, g) of the broiler breeder hens (y = - 699 + 0,347 x, Standard deviation = 75, R^2 = 0,74)

(see addendum 42 for statistical analysis)

Average egg weight was significantly ($P < 0,01$) increased by the higher energy intake, but this could not be explained by excess energy consumed. In Fig. 56 the correlation between average egg weight and excess energy for the total production period (week 23 - 61) is illustrated. This correlation was not significant ($P < 0,22$) but the trendline indicate as could be expected that egg weight increase with increasing excess energy consumed. This could also indicate that the higher energy levels was not in excess of requirement for egg weight.

The significant ($P < 0,012$) correlation between excess energy and chicks produced supports the finding in Chapter 2 that excess energy resulted in less chicks produced in the final period of production (Fig. 57).

The protein content of the carcass remained surprisingly constant between treatments and at different ages. This is in agreement with results of Fuller et al., (1969). It would appear that the animal is able to a high degree to maintain its essential protein composition, regardless of differences in age, mass, or nutrient intake (Gous, 1972).

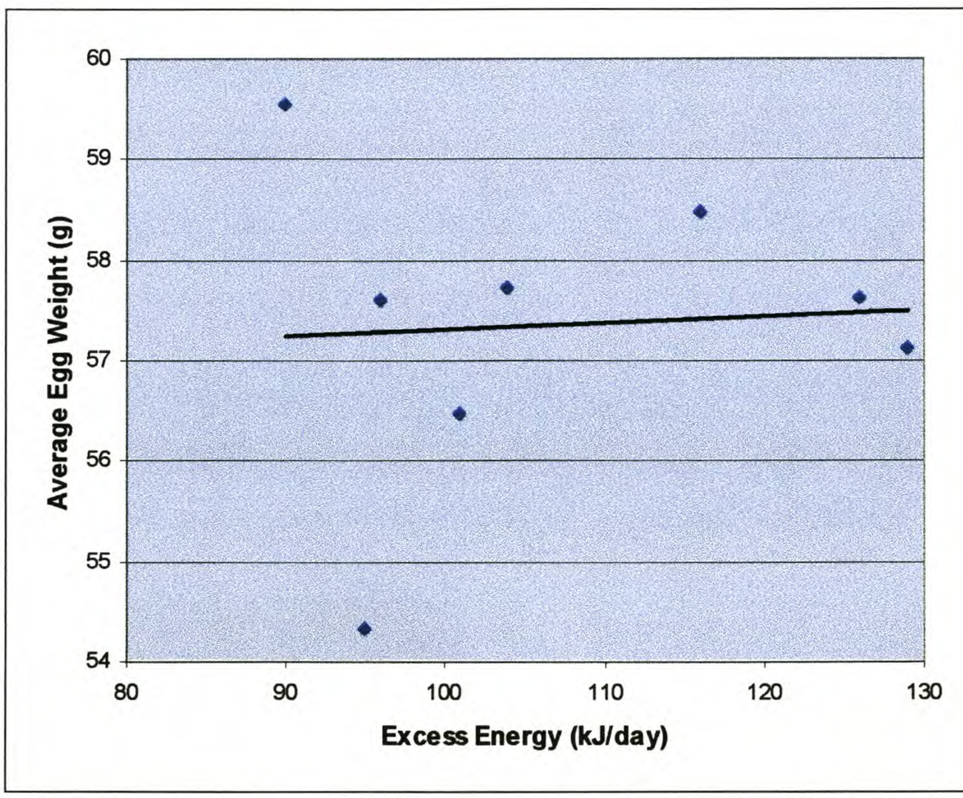


FIGURE 56 : The correlation between the average egg weight (y, g) and the excess energy consumed (x, kJ/day) of the broiler breeder hens for the total period week 23 to 61 (y = 60,4 + 0,0482 x, Standard deviation = 2,2, R^2 = 0,22)

(see addendum 45 for statistical analysis)

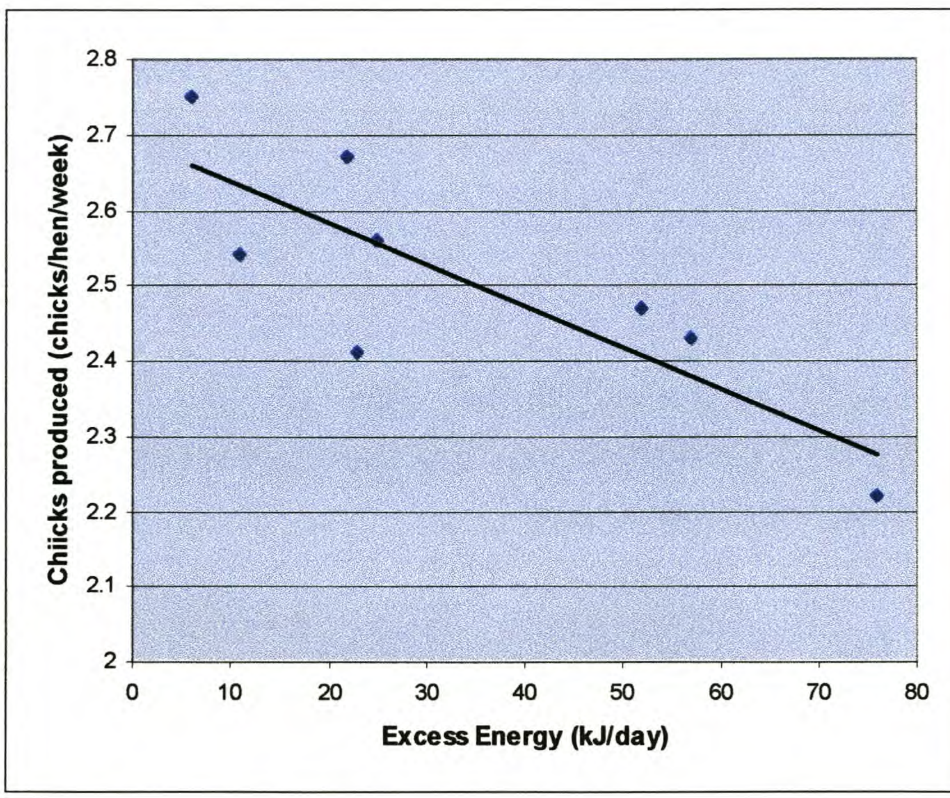


FIGURE 57 : The correlation between chicks produced (y, chicks/hen/week) and the excess energy consumed (x, kJ/day) of the broiler breeder hens for the period week 49 to 61 (y = 2,69 - 0,00548 x, Standard deviation = 0,06, R^2 = 0,68)

(see addendum 46 for statistical analysis)

3.6 CALCULATION OF LYSINE REQUIREMENTS

Lysine requirements were calculated by an equation published by Emmans and Fisher (1986) and takes the following compounds into consideration.

- $Lys_{maintenance} = (P / P_m{}^{0,27})$ x 0,008 x % lysine in carcass protein

  Where :

  P_m = mature weight (kg) taken as 0,706 kg for all treatments

  P = protein weight (kg)

  % lysine in carcass = 7,5 % of protein content

  0,008 = a value from Table 2.4 of Emmans & Fisher (1986).

- Lys_{growth} = Weight gain (g) x % protein of weight gain x % lysine in gain ÷ k

  Where:

  Weight gain = daily weight gain in g

  % lisine in carcass = 7,5 % of protein content

  k = the efficiency of utilization of lysine (80 %)

- Lys_{eggs} = Egg mass (g) x 0,0099

  Where:

  Egg mass = daily production of eggs in g

  0,99 = a value from Table 2 of McDonald & Morris (1985).

- $Lys_{feathers}$ = Feather growth (g) x % protein of feather growth x % lysine in feather ÷ k

Where:

Feather gain = 2 % of feather weight was taken as the daily feather growth. Feather weight was taken as 5,2 % of body weight.

% lisine in carcass = 7,5 % of protein content

k = the efficiency of utilization of lysine (80 %)

As with the calculation of the excess energy values the tritiated water values was used to determine the protein content of the carcass at various ages during the production period. The correlation equation Protein % = 9,55 + 0,117 x Waterspace % was used to estimate body protein content. The calculated lysine requirement for the breeders during the various periods is given in Table 21.

Table 21: **Analyses of Lysine Requirement and Lysine supplied to the breeders.**

Treatment Daily nutrient intake		Time period (weeks)	Feed intake (g/day)	Lysine content of feed (%)	Waterspace as % of body weight a	Body protein as derived from waterspace (%) b	Average hen weight at end of period (kg)	Body weight gain (g/day)	Egg mass produced (g/day)	Feather growth (g/day)
2000 kJ ME	900 mg Lys	21-26	131.66	0.563	69.91	17.80	3.096	20.98	6.21	3.2
		27-35	160.00	0.563	64.54	17.10	3.453	04.83	44.30	3.6
		36-43	160.00	0.563	62.43	16.82	3.727	04.79	45.10	3.9
		44-52	157.75	0.563	62.08	16.78	3.953	03.81	40.81	4.1
		53-61	151.00	0.563	60.18	16.53	4.093	02.12	35.36	4.3
	1050 mg Lys	21-26	131.66	0.656	69.50	17.75	3.126	22.19	06.20	3.3
		27-35	160.00	0.656	66.31	17.33	3.470	05.32	45.20	3.6
		36-43	160.00	0.656	63.85	17.01	3.682	03.64	47.49	3.8
		44-52	157.75	0.656	65.54	17.23	3.846	02.68	40.46	4
		53-61	151.00	0.656	65.37	17.21	3.943	02.73	36.39	4.1
	1200 mg Lys	21-26	131.66	0.750	73.50	18.27	3.273	24.67	07.16	3.4
		27-35	160.00	0.750	67.80	17.53	3.589	04.81	45.16	3.7
		36-43	160.00	0.750	63.92	17.02	3.815	04.07	46.82	4
		44-52	157.75	0.750	63.80	17.00	3.964	02.83	42.73	4.1
		53-61	151.00	0.750	63.61	16.98	4.082	02.00	34.47	4.3
	1350 mg Lys	21-26	131.66	0.844	69.76	17.78	3.226	25.67	06.17	3.4
		27-35	160.00	0.844	67.48	17.48	3.611	06.27	45.83	3.8
		36-43	160.00	0.844	63.46	16.96	3.868	04.57	49.56	4
		44-52	157.75	0.844	64.26	17.06	3.957	01.54	42.20	4.1
		53-61	151.00	0.844	61.70	16.73	4.143	03.05	32.99	4.3
1800 kJ ME	900 mg Lys	21-26	123.33	0.625	72.23	18.11	2.905	17.79	05.16	3
		27-35	144.11	0.625	68.14	17.57	3.202	04.57	40.22	3.3
		36-43	144.00	0.625	64.75	17.13	3.312	01.94	44.79	3.4
		44-52	141.33	0.625	65.51	17.23	3.433	01.83	40.46	3.6
		53-61	136.00	0.625	68.19	17.58	3.459	00.48	34.48	3.6
	1050 mg Lys	21-26	123.30	0.729	71.84	18.06	2.962	19.48	05.83	3.1
		27-35	144.10	0.729	67.89	17.54	3.302	05.00	43.24	3.4
		36-43	144.00	0.729	65.21	17.19	3.468	03.05	45.40	3.6
		44-52	141.30	0.729	65.28	17.20	3.598	02.00	40.25	3.7
		53-61	136.00	0.729	64.81	17.14	3.624	00.44	36.87	3.8
	1200 mg Lys	21-26	123.30	0.833	71.33	17.99	3.039	22.00	06.13	3.2
		27-35	144.10	0.833	66.65	17.38	3.324	04.33	44.88	3.5
		36-43	144.00	0.833	64.64	17.11	3.444	02.11	46.08	3.6
		44-52	141.30	0.833	64.25	17.06	3.567	02.00	43.36	3.7
		53-61	136.00	0.833	65.54	17.23	3.635	01.06	37.03	3.8
	1350 mg Lys	21-26	123.30	0.903	72.06	18.08	2.989	20.76	05.75	3.1
		27-35	144.10	0.903	67.79	17.53	3.401	05.63	45.19	3.5
		36-43	144.00	0.903	64.03	17.03	3.540	02.46	46.53	3.7
		44-52	141.30	0.903	64.42	17.08	3.662	02.10	43.43	3.8
		53-61	136.00	0.903	64.99	17.16	3.848	02.86	39.03	4

a – Waterspace as % of body weight as determined by tritiated water

b – Protein derived from waterspace = 9.55 + 0.117 (waterspace)

Table 21 (continued)

Treatment Daily nutrient intake		Time period (weeks)	Lysine for maintenance (mg/day)	Lysine for egg production (mg/day)	Lysine for weight gain (mg/day)	Lysine for feather growth (mg/day)	Total lysine requirement (mg/day) c	Lysine intake (mg/day)	Excess lysine consumed (mg/day)
2000 kJ ME	900 mg Lys	21-26	435	61	419	58	973	741	-231
		27-35	455	439	91	65	1049	901	-148
		36-43	487	446	89	70	1092	901	-191
		44-52	528	404	72	74	1078	888	-190
		53-61	531	350	39	77	997	850	-147
	1050 mg Lys	21-26	437	61	442	59	999	864	-135
		27-35	479	447	104	65	1095	1050	-46
		36-43	495	470	70	69	1103	1050	-54
		44-52	550	401	54	72	1077	1035	-42
		53-61	568	360	56	74	1058	991	-67
	1200 mg Lys	21-26	513	71	55	61	1194	987	-207
		27-35	521	447	99	67	1135	1200	65
		36-43	523	464	79	71	1137	1200	63
		44-52	552	423	56	74	1105	1183	78
		53-61	574	341	40	76	1032	1133	101
	1350 mg Lys	21-26	463	61	523	60	1108	1111	4
		27-35	523	454	129	68	1173	1350	178
		36-43	528	491	89	72	1180	1350	170
		44-52	556	418	31	74	1079	1331	252
		53-61	561	327	59	78	1024	1274	251
1800 kJ ME	900 mg Lys	21-26	413	51	360	54	879	771	-108
		27-35	440	398	89	60	988	901	-87
		36-43	428	443	36	62	970	900	-70
		44-52	462	401	35	64	962	883	-79
		53-61	497	341	10	65	913	850	-63
	1050 mg Lys	21-26	423	58	396	55	932	899	-33
		27-35	459	428	99	62	1048	1050	2
		36-43	466	449	58	65	1039	1050	11
		44-52	494	398	39	67	999	1030	31
		53-61	494	365	9	68	936	991	56
	1200 mg Lys	21-26	436	61	449	57	1002	1027	25
		27-35	451	444	84	62	1041	1200	159
		36-43	455	456	40	64	1015	1200	185
		44-52	476	429	38	67	1010	1177	167
		53-61	505	367	21	68	960	1133	173
	1350 mg Lys	21-26	431	57	426	56	970	1114	143
		27-35	480	447	113	64	1104	1301	197
		36-43	468	461	46	66	1041	1300	259
		44-52	497	430	41	69	1036	1276	239
		53-61	543	386	57	72	1059	1228	169

c – Total lysine requirement (mg/day) = Lysine for maintenance + Lysine for egg production + Lysine for weight gain

From Table 21 it was clear that the lysine requirements were more than 1050 mg/day to meet the breeder's needs. This was clear at both the energy levels but the effect was more pronounced at the higher energy levels (Fig. 58 and 59). The higher energy intake resulted in higher body weights and this increased the demand for lysine for maintenance (Table 20). In Chapter 2 no significant effect of the amount of lysine was noticed on hen day production, but it was noticed that the production was the lowest at the lowest level of lysine intake of 900 mg/day.

3.7 RELATIONSHIP BETWEEN PRODUCTION AND EXCESS LYSINE

The excess lysine calculated was correlated with the production results. The excess lysine values were to correspond with the production periods as given in Chapter 2. It was found that the egg output was significantly ($P < 0,05$) improved by increasing amino acid levels (Table 9) for the period week 36 to 48 and the total period of production. Excess lysine consumed for week 36 to 48 resulted in a significant ($P < 0,028$) relationship with egg output (Fig. 60). A significant ($P < 0,052$) relationship was also found for the total period (Fig. 61).

No correlation between excess lysine consumed and egg weight was found but from the graph the positive correlation with increasing levels of lysine for the total period is clear (Fig. 62).

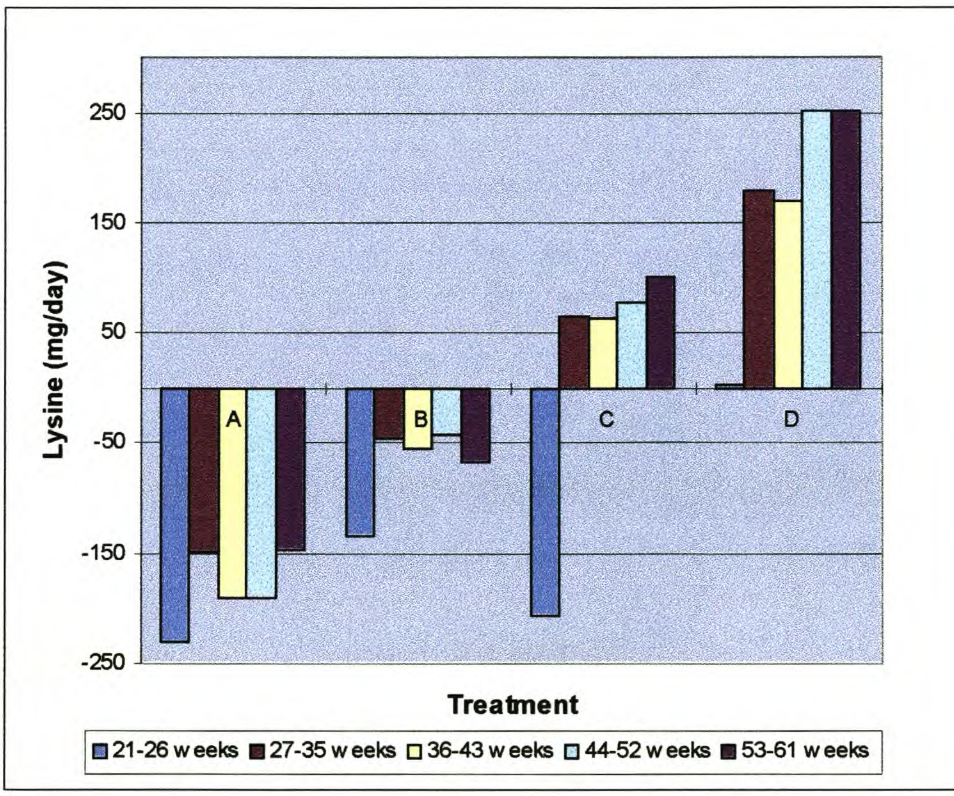


FIGURE 58: **The excess Lysine consumed (mg/day) by breeders receiving 2000 kJ/day energy and where E = 900 mg lys/day; F = 1050 mg lys/day; G = 1200 mg lys/day and H = 1350 mg lys/day.**

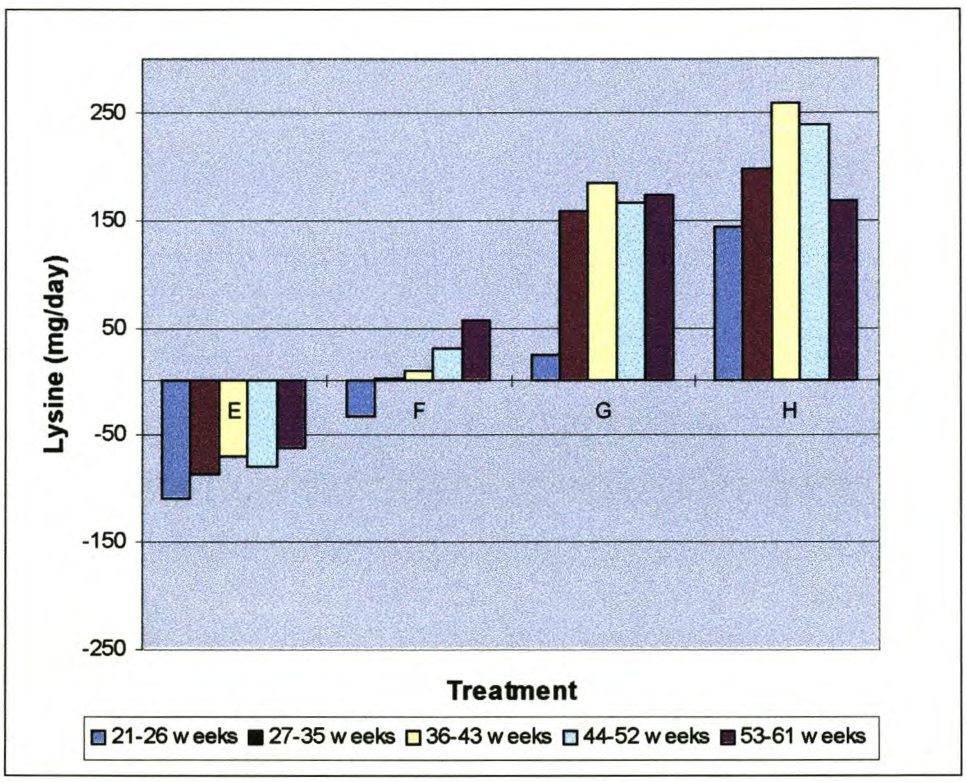


FIGURE 59: The excess Lysine consumed (mg/day) by breeders receiving 1800 kJ/day energy and where E = 900 mg lys/day; F = 1050 mg lys/day; G = 1200 mg lys/day and H = 1350 mg lys/day.

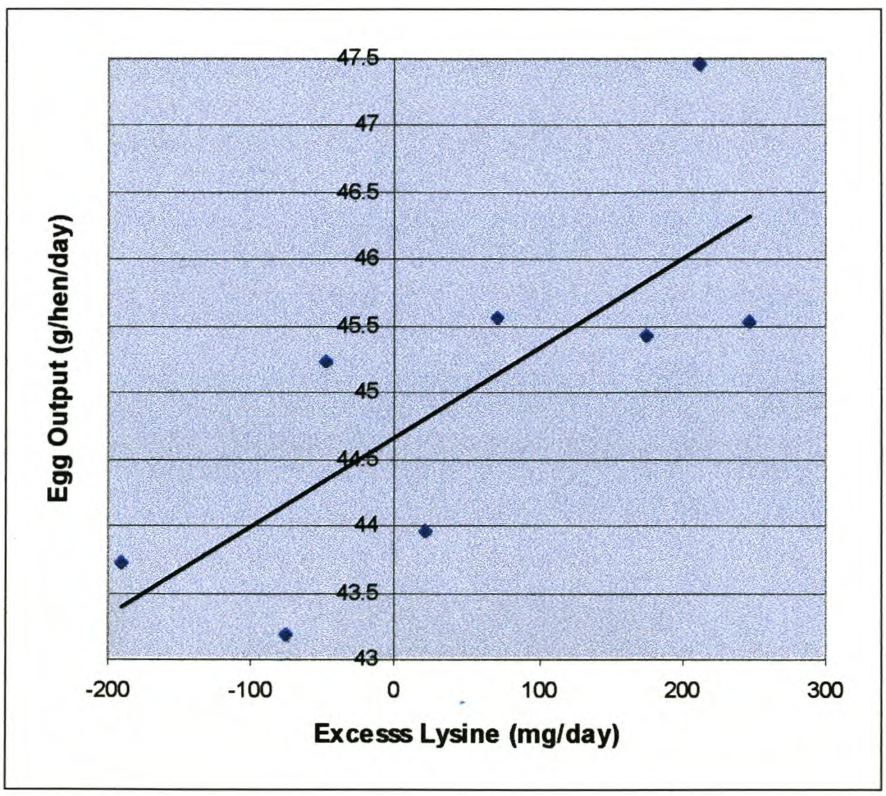


FIGURE 60: **The correlation between Egg Output (y, g) and the excess lysine consumed (x, mg/day) of the broiler breeder hens for the period week 36 to 48 (y = 44,7 + 0,00671x, Standard deviation = 0,36, R^2 = 0,51).**

(see addendum 47 for statistical analysis)

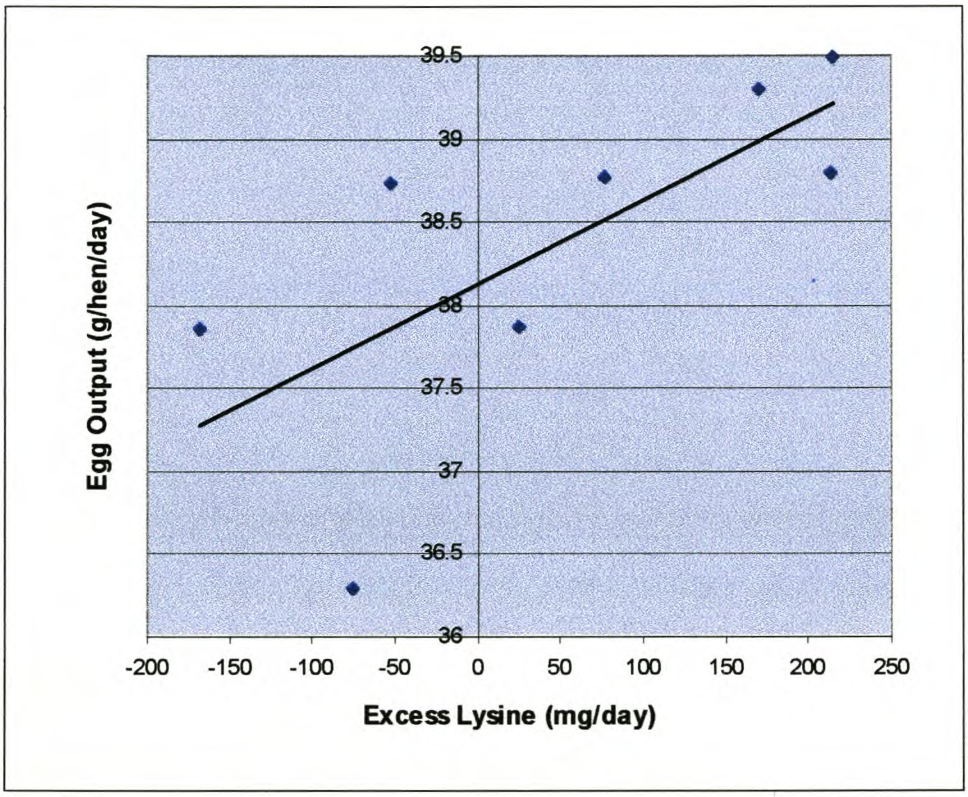


FIGURE 61: **The correlation between egg output (y, g) and the excess lysine consumed (x, mg/day) of the broiler breeder hens for the period week 23 to 61 (y = 38,1 + 0,00505 x, Standard deviation = 0,3, R^2 = 0,41).** (see addendum 48 for statistical analysis)

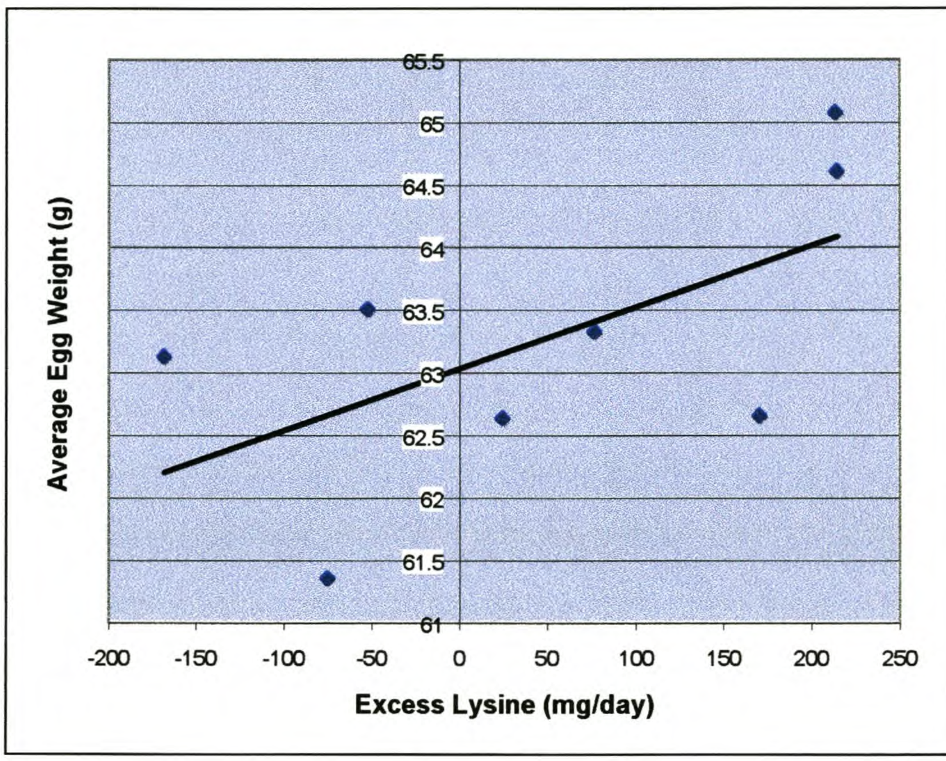


FIGURE 62: The correlation between average egg weight (y, g) and the excess energy consumed (x, mg/day) of the broiler breeder hens for the period week 23 to 61 (y = 63 + 0,00492 x, Standard deviation = 0,38, R^2 = 0,26).

Maintenance needs are by far the largest single factor affecting energy requirements of the breeder. Secondly it is egg production and lastly, growth and activity. In terms of protein needs, egg production and maintenance are the only two meaningful factors. However, as the bird gets older, the actual nutrient needs and the distribution of these needs change. At the end of the production period the bird needs less energy and protein for eggs, because egg production has declined (even though egg size has increased) but she needs more of these nutrients for maintenance because the bird has grown. At the end of the production period, we expect a significantly reduced growth rate, and so both protein and energy needs for growth are greatly reduced. The reduction in nutrient needs for lower egg production and less growth outweighs the needs for more maintenance, and the bottom line is overall reduction in daily need of the hen for both energy and protein.

The consequence of not reducing nutrient intake of the breeder hen after peak is that the oversupply of nutrients goes directly to increased growth which itself quickly causes an increased maintenance requirement. This extra growth will mainly be as fat, but there will also be some muscle (protein) growth. Obesity quickly leads to reduced egg production, diverting even more nutrients into growth (fat). This vicious circle is often responsible for the very sudden drop in egg production seen with flocks that are overfed after peak egg production.

Chapter 4

SUMMARY AND GENERAL DISCUSSION

Results of this study indicated that an energy intake of 2000 kJ ME/day for broiler breeders significantly decreased production in the period 49 - 61 weeks of age as opposed to birds consuming 1800 kJ ME/day. This negative effect of the higher energy intake was also confirmed by a significant ($P < 0{,}017$) negative correlation between energy consumed in excess of calculated requirements, and hen day production. An apparent beneficial effect of a high energy intake at low protein levels in the first period of production (23 - 35 weeks of age) was not significant. These results confirm previous work where it was found that ad libitum feeding of breeders have a negative effect on production (Robbins et al., 1986; Kantanbaf et al., 1989; Robinsons et al., 1991b and Yu et al., 1992). The feed intake of breeders during the laying period must thus be carefully controlled to ensure a high level of egg production (Pym and Dillon, 1974 and Blair et al., 1976).

Regarding protein intake it was found that egg production reached a plateau at 1050 to 1200 mg lysine/day/bird, however egg weight continued to increase at the highest intake of 1350 mg lysine/day/bird.

Energy and protein intake had significant (P < 0,01) effects on the average egg weight (g/egg). The beneficial (P < 0,01) effect of protein was consistent during all three periods of production and there was a tendency for egg weight to increase with increasing protein intake. However, differences were only statistically significant for the highest (1350 mg lysine) levels of intake.

Total egg mass responded significantly (P < 0,05) to increasing levels of protein, regardless of energy level, over the total production period. No interaction between protein and energy was found. The high energy level (2000 kJ ME) resulted in significant higher egg mass per hen only during the first period of production (week 23 to 35).

Hatchability was adversely affected by the higher energy intake for the total period of production (P < 0,05) and this effect was especially noticeable during the last production period, viz. week 49 - 61 (P < 0,01). Most of the problems found with body weights are related to the production of unsettable eggs. Ad libitum fed hens that lay erratically have reduced eggshell quality, presumably due to uncoordinated ovulation, oviposition or shell deposition (Jaap & Muir, 1968 and Katenbaf et al., 1989). Amino acid intake did not have a significant effect on hatchability in this study.

Energy was found to have a significant ($P < 0,05$) negative effect on the amount of chicks produced during the third period of production (week 49 - 61). This is similar to the hen day production results. The significant ($P < 0,012$) negative correlation between excess energy and chicks produced explains this effect.

In the present study the effect of dietary treatments on fertility of males was not tested but indications from literature are that male fertility can have large effects on the number of chickens per breeder (Wilson et al., 1979 and 1987; Hocking, 1989 and Hocking and Duff, 1989). As body weight increases, males are more susceptible to mechanical disorders involving feet and leg problems, and such problems interfere with normal mating activity (Burke and Mauldin, 1985; Hocking and Duff, 1989). These problems due to overweight males were not observed in this study.

The effect of high energy intake and its consequence on body weight has been described as the main cause of low fertility associated with broiler breeder hens (Ingram and Wilson, 1987; McDaniel et al., 1981b and Morris and Gous, 1988). In this experiment, the fertility was higher for the birds receiving the lower energy diets except for the treatment receiving 1050 mg lysine/day.

The feed conversion was significantly ($P < 0,01$) lower at increasing levels of amino acid. Feed conversion in the first period of production was lower at the higher energy intake probably due to the higher level of egg output.

From 31 weeks to 51 weeks of age the daily weight gain was 3,9 g/day for the higher energy diets and 2,8 g/day for the lower energy diets. Both treatments were higher than the breeder indication of 2,13 g/day. The effect of the energy intake on hen weight was significant ($P < 0,05$) for the total period of production and protein had a very significant ($P < 0,01$) effect during the first period of production. It is expected that excess energy will be deposited as fat in the carcass. This is proved in this experiment by the correlation between excess energy and weight gain and between weight gain and fat content of the carcass.

There is a dramatic change in the nutrient demand of the young breeder at the onset of production. The energy requirement increases dramatically during this period. Proper timing and availability of the required nutrients in the six to eight weeks of early production must be programmed effectively. The hen's fat reserve becomes important as they come into peak production. Insufficient energy intake causes a flock to plateau in weight gain and production. Birds will draw upon their reserves to provide energy for egg production. When depleted, they will rest in order to deposit muscle causing a characteristic post peak dip in egg production. Adequate body weight gain between 22 and 30 weeks may be a much more sensitive criterion in maximizing performance than was previously believed (Harms, 1984). The required weekly increments of growth must be maintained to achieve physical maturity at 30 weeks together with good physical and sexual uniformity to preserve physical condition for mating. During the pre-breeding period the reproductive organs develop, the liver increase in size and the estrogen dependent hepatic biosynthetic pathways are activated. Thus, the rate at which the daily food allocation should be increased, and the age (or stage of development) when this is initiated, is of considerable importance. If the increments are too small, the pullets may not be capable of developing their reproductive organs at the normal rate, nor might they receive the necessary stimulus to begin laying. On the other hand, if the increments are large and at a high frequency, the advantages accrued by restricting growth rate during rearing would be undone and apart from a lower egg output, mortality may increase. The development of an egg weight profile is also seen as a useful indicator of nutritional status.

The new concept of feeding females and males separately allows the producer to control the feed intake of the male in order to restrict the adult body weight. This system also permits the use of diets formulated specifically for each sex.

The present study has again demonstrated the usefulness of an isotope dilution technique (tritiated water) in the estimation of body composition in vivo in poultry. The accuracy of prediction equations based on isotope dilution space will be influenced by the degree of overestimation of total body water. It was found that the tritiated water only overestimated the moisture content of the carcass between 2,61 to 7,41 % and this is in agreement with work of Johnson and Farrell (1988).

A significant ($P < 0,01$) correlation between moisture content of the carcass and tritiated water was established which illustrated that the indirect method of tritiated water also provides an accurate prediction of the water content of the carcass. The relationship between waterspace and fat as well as between waterspace and protein was used to determine carcass composition of broiler breeder females over time. From the body composition the energy and lysine requirements could be calculated. Using the Effective Energy system the results of this study indicated that the energy requirements of the breeders were not adequately met by the lower energy level, viz. 1800 kJ per hen per day. The ME system, however, indicated that energy intake were sufficient at both energy levels. This is clearly an indication of the ME system's inability to take into consideration the efficiency with which energy from fat, carbohydrates and protein is utilized for maintenance, growth and production (De Groote, 1974). The calculated energy requirements during peak production for breeders in this experiment amounted to 1942 kJ EE/day or 1746 kJ ME/day. This occurred during the period of 36 to 43 weeks of age. Decreases in production were highly correlated with excesses in energy consumption.

Lysine, and thus protein, requirements were also calculated from body composition data obtained from tritiated water and indicated that the requirement of breeder females are in excess of 1050 mg lysine per day but less than 1300 mg per day. The breeder company's recommendation of 1200 mg lysine/day/hen and 1900 kJ ME/hen/day. It is thus concluded that 1200 mg/hen/day should be fed, which is also the breeder company's recommendation.

With regard to energy 1800 kJ/day resulted in the highest production as opposed to 2000 kJ/day. However feeding more energy in the beginning of the laying period appears to be beneficial. It is therefore recommended that the energy intake of breeders should be between 1900 - 2000 kJ/day from week 23 - 35 and that the level should then be reduced to 1800 kJ/day for the remainder of the period.

It can thus be concluded that the feeding of broiler breeders requires a delicate balance between feeding for the onset of production and obtaining maximal number of eggs per hen over the entire laying period was one of the main findings which emerged with this study. It is not recommended to study nutrient requirements in isolation for particular periods without taking into consideration the effect of treatments in the other periods of the hen's life.

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Poultry Science 71 : 1750 – 1761.

ADDENDUM 1

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for hen day production - period 1

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	4,140	4,140	4,140	0,42	0,522
protein	3	32,730	32,730	10,910	1,11	0,363
energy*protein	3	13,364	13,364	4,455	0,45	0,716
Error	24	235,057	235,057	9,794		
Total	31	285,291				

Means for hen day production - period 1

energy		mean	Standard deviation
1		58,14	0,7824
2		57,42	0,7824
protein			
1		56,62	1,1065
2		58,10	1,1065
3		59,27	1,1065
4		57,14	1,1065
energy*protein			
1	1	57,85	1,5648
1	2	58,83	1,5648
1	3	59,07	1,5648
1	4	56,81	1,5648
2	1	55,39	1,5648
2	2	57,37	1,5648
2	3	59,46	1,5648
2	4	57,46	1,5648

LSD-value for energy = 2,284
LSD-value for protein = 3,230

ADDENDUM 2

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for hen day production - period 2

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Energy	1	2,040	2,040	2,040	0,23	0,636
Protein	3	34,445	34,445	11,482	1,29	0,301
energy*protein	3	25,029	25,029	8,343	0,94	0,438
Error	24	213,651	213,651	8,902		
Total	31	275,165				

Means for hen day production - period 2

energy		Mean	standard deviation
1		70,07	0,7459
2		69,57	0,7459
protein			
1		68,31	1,0549
2		69,64	1,0549
3		71,19	1,0549
4		70,13	1,0549
energy*protein			
1	1	67,75	1,4918
1	2	70,10	1,4918
1	3	70,69	1,4918
1	4	71,75	1,4918
2	1	68,86	1,4918
2	2	69,18	1,4918
2	3	71,70	1,4918
2	4	68,52	1,4918

LSD-value for energy = 2,177
LSD-value for protein = 3,079

ADDENDUM 3

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for hen day production - period 3

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	69,00	69,00	69,00	4,63	0,042
protein	3	14,81	14,81	4,94	0,33	0,803
energy*protein	3	61,03	61,03	20,34	1,36	0,278
Error	24	358,05	358,05	14,92		
Total	31	502,89				

Means for hen day production - period 3

energy	Mean	standard deviation
1	52,92 **a**	0,9656
2	55,86 **b**	0,9656
protein		
1	53,60	1,3656
2	54,62	1,3656
3	55,38	1,3656
4	53,96	1,3656
energy*protein		
1 1	53,38	1,9312
1 2	54,20	1,9312
1 3	53,86	1,9312
1 4	50,26	1,9312
2 1	53,83	1,9312
2 2	55,05	1,9312
2 3	56,90	1,9312
2 4	57,66	1,9312

LSD-value for energy = 2,819
LSD-value for protein = 3,986

ADDENDUM 4

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for hen day production - total period

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	1,985	1,985	1,985	0,45	0,508
Protein	3	23,055	23,055	7,685	1,75	0,184
Energy*protein	3	7,794	7,794	2,598	0,59	0,627
Error	24	105,552	105,552	4,398		
Total	31	138,385				

Means for hen day production - total period

energy		mean	standard deviation
1		60,43	0,5243
2		60,92	0,5243
protein			
1		59,61	0,7414
2		60,75	0,7414
3		61,96	0,7414
4		60,38	0,7414
energy*protein			
1	1	59,86	1,0486
1	2	60,99	1,0486
1	3	61,23	1,0486
1	4	59,63	1,0486
2	1	59,36	1,0486
2	2	60,51	1,0486
2	3	62,69	1,0486
2	4	61,13	1,0486

LSD-value for energy = 1,530
LSD-value for protein = 2,164

ADDENDUM 5

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for egg weight - period 1

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	17,287	17,287	17,287	11,22	0,003
protein	3	44,306	44,306	14,769	9,58	0,000
energy*protein	3	4,755	4,755	1,585	1,03	0,398
Error	24	36,982	36,982	1,541		
Total	31	103,33				

Means for egg weight - period 1

energy		mean	standard deviation
1		57,97 **a**	0,3103
2		56,5 **b**	0,3103
protein			
1		55,71 **a**	0,4389
2		57,03 **b**	0,4389
3		57,17 **b**	0,4389
4		59,01 **c**	0,4389
energy*protein			
1	1	57,11	0,6207
1	2	57,60	0,6207
1	3	57,61	0,6207
1	4	59,55	0,6207
2	1	54,31	0,6207
2	2	56,47	0,6207
2	3	56,72	0,6207
2	4	58,48	0,6207

LSD-value for energy = 0,906
LSD-value for protein = 1,281

ADDENDUM 6

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for egg weight - period 2

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	6,625	6,625	6,625	3,44	0,076
protein	3	37,999	37,999	12,666	6,58	0,002
energy*protein	3	4,577	4,577	1,526	0,79	0,510
Error	24	46,184	46,184	1,924		
Total	31	95,385				

Means for egg weight - period 2

energy		mean	standard deviation
1		64,93	0,3468
2		64,02	0,3468
protein			
1		63,61 **a**	0,4905
2		64,04 **a**	0,4905
3		63,90 **a**	0,4905
4		66,34 **b**	0,4905
energy*protein			
1	1	64,52	0,6936
1	2	64,53	0,6936
1	3	64,46	0,6936
1	4	66,20	0,6936
2	1	62,70	0,6936
2	2	63,55	0,6936
2	3	63,33	0,6936
2	4	66,48	0,6936

LSD-value for energy = 1,012
LSD-value for protein = 1,431

ADDENDUM 7

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for egg weight - period 3

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	3,8434	3,8434	3,8434	5,73	0,025
protein	3	15,9867	15,9867	5,3289	7,94	0,001
energy*protein	3	2,5322	2,5322	0,8441	1,26	0,311
Error	24	16,1113	16,1113	0,6713		
Total	31	38,4736				

Means for egg weight - period 3

energy		mean	standard deviation
1		69,16 **a**	0,2048
2		68,47 **b**	0,2048
Protein			
1		68,12 **a**	0,2897
2		68,72 **a**	0,2897
3		68,44 **a**	0,2897
4		69,98 **b**	0,2897
energy*protein			
1	1	68,86	0,4097
1	2	69,18	0,4097
1	3	68,62	0,4097
1	4	69,98	0,4097
2	1	67,38	0,4097
2	2	68,25	0,4097
2	3	68,26	0,4097
2	4	69,99	0,4097

LSD-value for energy = 0,598
LSD-value for protein = 0,846

ADDENDUM 8

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for egg weight - total period

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Energy	1	7,1726	7,1726	7,1726	8,60	0,007
Protein	3	29,1153	29,1153	9,7051	11,64	0,000
energy*protein	3	1,9608	1,9608	0,6536	0,78	0,515
Error	24	20,0086	20,0086	0,8337		
Total	31	58,2573				

Means for egg weight - total period

Energy		Mean	standard deviation
1		63,75 **a**	0,2283
2		62,81 **b**	0,2283
Protein			
1		62,24 **a**	0,3228
2		63,06 **a**	0,3228
3		62,99 **a**	0,3228
4		64,83 **b**	0,3228
energy*protein			
1	1	63,12	0,4565
1	2	63,50	0,4565
1	3	63,32	0,4565
1	4	65,07	0,4565
2	1	61,35	0,4565
2	2	62,63	0,4565
2	3	62,65	0,4565
2	4	64,60	0,4565

LSD-value for energy = 0,666
LSD-value for protein = 0,942

ADDENDUM 9

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for egg mass - period 1

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	12,954	12,954	12,954	4,31	0,049
protein	3	26,993	26,993	8,998	2,99	0,051
energy*protein	3	9,765	9,765	3,255	1,08	0,376
Error	24	72,215	72,215	3,009		
Total	31	121,927				

Means for egg mass - period 1

Energy		mean	Standard deviation
1		33,70 **a**	0,4337
2		32,43 **b**	0,4337
Protein			
1		31,56 **a**	0,6133
2		33,10 **ab**	0,6133
3		33,88 **b**	0,6133
4		33,73 **b**	0,6133
energy*protein			
1	1	33,04	0,8673
1	2	33,88	0,8673
1	3	34,04	0,8673
1	4	33,85	0,8673
2	1	30,08	0,8673
2	2	32,31	0,8673
2	3	33,72	0,8673
2	4	33,60	0,8673

LSD-value for energy = 1,266
LSD-value for protein = 1,790

ADDENDUM 10

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for egg mass - period 2

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	7,469	7,469	7,469	2,08	0,162
protein	3	40,151	40,151	13,384	3,72	0,025
energy*protein	3	3,770	3,770	1,257	0,35	0,790
Error	24	86,281	86,281	3,595		
Total	31	137,671				

Means for egg mass - period 2

Energy		Mean	standard deviation
1		45,49	0,4740
2		44,52	0,4740
protein			
1		43,45 **a**	0,6704
2		44,59 **ab**	0,6704
3		45,49 **b**	0,6704
4		46,49 **b**	0,6704
energy*protein			
1	1	43,72	0,9480
1	2	45,23	0,9480
1	3	45,55	0,9480
1	4	47,45	0,9480
2	1	43,18	0,9480
2	2	43,96	0,9480
2	3	45,42	0,9480
2	4	45,53	0,9480

LSD-value for energy = 1,384
LSD-value for protein = 1,957

ADDENDUM 11

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for egg mass - period 3

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	17,331	17,331	17,331	2,41	0,134
Protein	3	13,177	13,177	4,392	0,61	0,615
energy*protein	3	40,902	40,902	13,634	1,89	0,158
Error	24	172,843	172,843	7,202		
Total	31	244,253				

Means for egg mass - period 3

Energy		mean	standard deviation
1		36,67	0,6709
2		38,14	0,6709
protein			
1		36,33	0,9488
2		37,53	0,9488
3		37,91	0,9488
4		37,87	0,9488
energy*protein			
1	1	36,83	1,3418
1	2	37,50	1,3418
1	3	36,96	1,3418
1	4	35,40	1,3418
2	1	35,40	1,3418
2	2	35,81	1,3418
2	3	37,56	1,3418
2	4	38,86	1,3418

LSD-value for energy = 1,958
LSD-value for protein = 2,770

ADDENDUM 12

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for egg mass - total period

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	0,720	0,720	0,720	0,40	0,533
protein	3	21,726	21,726	7,242	4,02	0,019
energy*protein	3	7,078	7,078	2,359	1,31	0,294
Error	24	43,185	43,185	1,799		
Total	31	72,710				

Means for egg mass - total period

Energy		mean	Standard deviation
1		38,53	0,3354
2		38,24	0,3354
Protein			
1		37,07 **a**	0,4743
2		38,30 **ab**	0,4743
3		39,03 **b**	0,4743
4		39,14 **b**	0,4743
energy*protein			
1	1	37,85	0,6707
1	2	38,73	0,6707
1	3	38,77	0,6707
1	4	38,79	0,6707
2	1	36,29	0,6707
2	2	37,87	0,6707
2	3	39,29	0,6707
2	4	39,49	0,6707

LSD-value for energy = 0,979
LSD-value for protein = 1,384

ADDENDUM 13

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for fertility - period 1

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	1,374	1,374	1,374	0,28	0,605
protein	3	2,977	2,977	0,992	0,20	0,896
energy*protein	3	36,493	36,493	12,164	2,44	0,089
Error	24	119,715	119,715	4,988		
Total	31	160,558				

Means for fertility - period 1

Energy		Mean	Standard deviation
1		91,60	0,5584
2		92,01	0,5584
Protein			
1		92,05	0,7896
2		91,30	0,7896
3		92,05	0,7896
4		91,82	0,7896
energy*protein			
1	1	93,13	1,167
1	2	91,79	1,167
1	3	91,34	1,167
1	4	90,14	1,167
2	1	90,97	1,167
2	2	90,82	1,167
2	3	92,76	1,167
2	4	93,50	1,167

LSD-value for energy = 1,630
LSD-value for protein = 2,305

ADDENDUM 14

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for fertility - period 2

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	3,699	3,699	3,699	1,88	0,183
protein	3	17,299	17,299	5,766	2,92	0,054
energy*protein	3	11,937	11,937	3,979	2,02	0,138
Error	24	47,325	47,325	1,972		
Total	31	80,261				

Means for fertility - period 2

Energy		Mean	standard deviation
1		93,66	0,3511
2		94,34	0,3511
Protein			
1		93,96	0,4965
2		93,42	0,4965
3		95,21	0,4965
4		93,41	0,4965
energy*protein			
1	1	93,67	0,7021
1	2	93,68	0,7021
1	3	95,24	0,7021
1	4	92,06	0,7021
2	1	94,25	0,7021
2	2	93,17	0,7021
2	3	95,19	0,7021
2	4	94,75	0,7021

LSD-value for energy = 1,025
LSD-value for protein = 1,449

ADDENDUM 15

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for fertility - period 3

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	0,54	0,54	0,54	0,03	0,872
Protein	3	31,34	31,34	10,45	0,51	0,677
energy*protein	3	78,87	78,87	26,29	1,29	0,300
Error	24	488,53	488,53	20,36		
Total	31	599,28				

Means for fertility - period 3

Energy		Mean	standard deviation
1		87,91	1,128
2		87,65	1,128
Protein			
1		87,19	1,595
2		86,82	1,595
3		89,41	1,595
4		87,69	1,595
energy*protein			
1	1	84,89	2,256
1	2	88,88	2,256
1	3	90,04	2,256
1	4	87,82	2,256
2	1	89,49	2,256
2	2	84,77	2,256
2	3	88,77	2,256
2	4	87,56	2,256

LSD-value for energy = 3,293
LSD-value for protein = 4,657

ADDENDUM 16

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for fertility - total period

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Energy	1	0,52	0,52	0,52	0,16	0,691
Protein	3	12,40	12,40	4,133	1,29	0,302
energy*protein	3	19,393	19,393	5,464	1,70	0,194
Error	24	77,198	77,198	3,217		
Total	31	106,512				

Means for fertility - total period

Energy		Mean	standard deviation
1		91,34	0,4484
2		91,63	0,4484
Protein			
1		91,44	0,6341
2		90,77	0,6341
3		92,49	0,6341
4		91,31	0,6341
energy*protein			
1	1	91,02	0,8967
1	2	91,73	0,8967
1	3	92,46	0,8967
1	4	90,30	0,8967
2	1	91,86	0,8967
2	2	89,82	0,8967
2	3	92,52	0,8967
2	4	92,32	0,8967

LSD-value for energy = 1,309
LSD-value for protein = 1,851

ADDENDUM 17

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for hatchability - period 1

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	9,946	9,946	9,946	1,03	0,319
protein	3	1,133	1,133	0,378	0,04	0,989
energy*protein	3	18,681	18,681	6,227	0,65	0,592
Error	24	230,642	230,642	9,610		
Total	31	260,401				

Means for hatchability - period 1

Energy		Mean	standard deviation
1		87,16	0,775
2		88,28	0,775
Protein			
1		87,69	1,096
2		87,85	1,096
3		87,92	1,096
4		87,43	1,096
energy*protein			
1	1	87,89	1,55
1	2	87,64	1,55
1	3	87,53	1,55
1	4	85,60	1,55
2	1	87,48	1,55
2	2	88,06	1,55
2	3	88,32	1,55
2	4	89,26	1,55

LSD-value for energy = 2,262
LSD-value for protein = 3,199

ADDENDUM 18

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for hatchability - period 2

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	21,797	21,797	21,797	7,01	0,014
protein	3	4,197	4,197	1,399	0,45	0,719
energy*protein	3	26,489	26,489	8,830	2,84	0,059
Error	24	74,575	74,575	3,107		
Total	31	127,058				

Means for hatchability - period 2

Energy		Mean	standard deviation
1		91,88 **a**	0,4407
2		93,53 **b**	0,4407
Protein			
1		93,16	0,6232
2		92,80	0,6232
3		92,15	0,6232
4		92,71	0,6232
energy*protein			
1	1	93,37	0,8814
1	2	92,71	0,8814
1	3	90,20	0,8814
1	4	91,23	0,8814
2	1	92,94	0,8814
2	2	92,89	0,8814
2	3	94,10	0,8814
2	4	94,19	0,8814

LSD-value for energy = 1,286
LSD-value for protein = 1,819

ADDENDUM 19

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for hatchability - period 3

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	115,37	115,37	115,37	8,42	0,008
protein	3	12,41	12,41	4,14	0,30	0,824
energy*protein	3	8,14	8,14	2,71	0,20	0,897
Error	24	328,75	328,75	13,70		
Total	31	464,67				

Means for hatchability - period 3

Energy	Mean	standard deviation
1	83,85 **a**	0,9253
2	87,64 **b**	0,9253
Protein		
1	86,76	1,3085
2	85,54	1,3085
3	85,61	1,3085
4	85,06	1,3085
energy*protein		
1 1	85,53	1,8505
1 2	83,25	1,8505
1 3	83,15	1,8505
1 4	83,46	1,8505
2 1	87,99	1,8505
2 2	87,83	1,8505
2 3	88,08	1,8505
2 4	86,66	1,8505

LSD-value for energy = 2,701
LSD-value for protein = 3,820

ADDENDUM 20

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for hatchability - total period

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	31,304	31,304	31,304	7,46	0,012
protein	3	1,870	1,870	0,623	0,15	0,930
energy*protein	3	10,955	10,955	3,652	0,87	0,470
Error	24	100,737	100,737	4,197		
Total	31	144,865				

Means for hatchability - total period

Energy		Mean	standard deviation
1		88,27 **a**	0,5122
2		90,25 **b**	0,5122
Protein			
1		89,66	0,7243
2		89,23	0,7243
3		89,11	0,7243
4		89,04	0,7243
energy*protein			
1	1	89,52	1,0244
1	2	88,48	1,0244
1	3	87,60	1,0244
1	4	87,48	1,0244
2	1	89,80	1,0244
2	2	89,98	1,0244
2	3	90,62	1,0244
2	4	90,60	1,0244

LSD-value for energy = 1,495
LSD-value for protein = 2,114

ADDENDUM 21

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for chicks - period 1

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	0,00813	0,00813	0,00813	0,17	0,681
protein	3	0,09986	0,09986	0,03329	0,71	0,556
energy*protein	3	0,38706	0,38706	0,12902	2,75	0,065
Error	24	1,12688	1,12688	0,04695		
Total	31	1,62192				

Means for chicks - period 1

Energy		Mean	standard deviation
1		2,451	0,05417
2		2,483	0,05417
Protein			
1		2,441	0,07661
2		2,464	0,07661
3		2,556	0,07661
4		2,405	0,07661
energy*protein			
1	1	2,570	0,10834
1	2	2,515	0,10834
1	3	2,450	0,10834
1	4	2,267	0,10834
2	1	2,312	0,10834
2	2	2,412	0,10834
2	3	2,663	0,10834
2	4	2,543	0,10834

LSD-value for energy = 0,158
LSD-value for protein = 0,224

ADDENDUM 22

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for chicks - period 2

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	0,01163	0,01163	0,01163	0,20	0,656
protein	3	0,38786	0,38786	0,12929	2,26	0,107
energy*protein	3	0,26101	0,26101	0,08700	1,52	0,234
Error	24	1,36993	1,36993	0,05708		
Total	31	2,03042				

Means for chicks - period 2

Energy		Mean	standard deviation
1		3,753	0,05973
2		3,791	0,05973
Protein			
1		3,684	0,08447
2		3,731	0,08447
3		3,960	0,08447
4		3,711	0,08447
energy*protein			
1	1	3,743	0,11946
1	2	3,810	0,11946
1	3	3,825	0,11946
1	4	3,633	0,11946
2	1	3,625	0,11946
2	2	3,652	0,11946
2	3	4,095	0,11946
2	4	3,790	0,11946

LSD-value for energy = 0,174
LSD-value for protein = 0,247

ADDENDUM 23

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for chicks - period 3

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	0,4851	0,4851	0,4851	4,49	0,045
protein	3	0,0734	0,0734	0,0245	0,23	0,877
energy*protein	3	0,1875	0,1875	0,0625	0,58	0,635
Error	24	2,5938	2,5938	0,1081		
Total	31	3,3398				

Means for chicks - period 3

Energy		Mean	standard deviation
1		2,381 **a**	0,08219
2		2,627 **b**	0,08219
Protein			
1		2,493	0,11623
2		2,501	0,11623
3		2,578	0,11623
4		2,444	0,11623
energy*protein			
1	1	2,428	0,16437
1	2	2,467	0,16437
1	3	2,405	0,16437
1	4	2,223	0,16437
2	1	2,557	0,16437
2	2	2,535	0,16437
2	3	2,750	0,16437
2	4	2,665	0,16437

LSD-value for energy = 0,240
LSD-value for protein = 0,339

ADDENDUM 24

Factor	Levels	Values			
Energy	2	1	2		
Protein	4	1	2	3	4

Analysis of Variance for chicks - total period

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Energy	1	0,0810	0,0810	0,0810	2,12	0,158
Protein	3	0,15478	0,15478	0,05159	1,35	0,282
Energy*protein	3	0,25856	0,25856	0,08619	2,25	0,108
Error	24	0,91758	0,91758	0,03823		
Total	31	1,41192				

Means for chicks - total period

Energy		Mean	standard deviation
1		2,863	0,04888
2		2,964	0,04888
Protein			
1		2,880	0,06913
2		2,896	0,06913
3		3,030	0,06913
4		2,848	0,06913
energy*protein			
1	1	2,928	0,0977
1	2	2,928	0,0977
1	3	2,892	0,0977
1	4	2,705	0,0977
2	1	2,832	0,0977
2	2	2,865	0,0977
2	3	3,168	0,0977
2	4	2,990	0,0977

LSD-value for energy = 0,143
LSD-value for protein = 0,202

ADDENDUM 25

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for chick weight - period 1

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	5,4946	5,4946	5,4946	9,19	0,006
protein	3	10,2273	10,2273	3,4091	5,70	0,004
energy*protein	3	5,2578	5,2578	1,7526	2,93	0,054
Error	24	14,3515	14,3515	0,5980		
Total	31	35,3312				

Means for chick weight - period 1

Energy		Mean	standard deviation
1		39,99 **a**	0,1933
2		39,17 **b**	0,1933
Protein			
1		38,89 **a**	0,2734
2		39,28 **ab**	0,2734
3		39,74 **ab**	0,2734
4		40,41 **b**	0,2734
Energy*protein			
1	1	39,87	0,3866
1	2	39,89	0,3866
1	3	39,78	0,3866
1	4	40,43	0,3866
2	1	37,91	0,3866
2	2	38,67	0,3866
2	3	39,69	0,3866
2	4	40,39	0,3866

LSD-value for energy = 0,564
LSD-value for protein = 0,798

ADDENDUM 26

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for chick weight - period 2

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	4,6971	4,6971	4,6971	6,06	0,021
protein	3	9,4809	9,4809	3,1603	4,07	0,018
energy*protein	3	0,3521	0,3521	0,1174	0,15	0,928
Error	24	18,6146	18,6146	0,7756		
Total	31	33,1448				

Means for chick weight - period 2

Energy		Mean	standard deviation
1		43,91 **a**	0,2202
2		43,14 **b**	0,2202
Protein			
1		43,15 **a**	0,3114
2		43,36 **a**	0,3114
3		43,13 **a**	0,3114
4		44,45 **b**	0,3114
energy*protein			
1	1	43,62	0,4403
1	2	43,67	0,4403
1	3	43,64	0,4403
1	4	44,71	0,4403
2	1	42,69	0,4403
2	2	43,05	0,4403
2	3	42,62	0,4403
2	4	44,20	0,4403

LSD-value for energy = 0,643
LSD-value for protein = 0,909

ADDENDUM 27

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for chick weight - period 3

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	7,135	7,135	7,135	5,03	0,034
protein	3	15,492	15,492	5,164	3,64	0,027
energy*protein	3	2,569	2,569	0,856	0,60	0,619
Error	24	34,027	34,027	1,418		
Total	31	59,224				

Means for chick weight - period 3

Energy		Mean	standard deviation
1		46,92 **a**	0,2977
2		45,97 **b**	0,2977
Protein			
1		46,31 **a**	0,4210
2		45,85 **a**	0,4210
3		46,01 **a**	0,4210
4		47,62 **b**	0,4210
energy*protein			
1	1	47,10	0,5954
1	2	46,57	0,5954
1	3	46,22	0,5954
1	4	47,79	0,5954
2	1	45,52	0,5954
2	2	45,13	0,5954
2	3	45,80	0,5954
2	4	47,44	0,5954

LSD-value for energy = 0,839
LSD-value for protein = 1,229

ADDENDUM 28

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for chick weight - total period

Source	DF	Seq SS	Adj SS	Adj MS	F	P
energy	1	4,4105	4,4105	4,4105	8,09	0,009
protein	3	9,1149	9,1149	3,0383	5,57	0,005
energy*protein	3	0,7287	0,7287	0,2429	0,45	0,723
Error	24	13,0856	13,0856	0,5452		
Total	31	27,3397				

Means for chick weight - total period

Energy		Mean	standard deviation
1		43,51 **a**	0,1846
2		42,77 **b**	0,1846
Protein			
1		42,74 **a**	0,2611
2		42,85 **a**	0,2611
3		42,91 **a**	0,2611
4		44,06 **b**	0,2611
energy*protein			
1	1	43,32	0,3692
1	2	43,31	0,3692
1	3	43,15	0,3692
1	4	44,28	0,3692
2	1	42,17	0,3692
2	2	42,40	0,3692
2	3	42,68	0,3692
2	4	43,84	0,3692

LSD-value for energy = 0,539
LSD-value for protein = 0,762

ADDENDUM 29

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for feed conversion - period 1

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Energy	1	21,190	21,190	21,190	8,54	0,007
Protein	3	484,012	484,012	161,337	65,03	0,000
energy*protein	3	13,767	13,767	4,589	1,85	0,165
Error	24	59,543	59,543	2,481		
Total	31	578,511				

Means for feed conversion - period 1

Energy	Mean	standard deviation
1	32,01 **a**	0,3938
2	30,39 **b**	0,3938
Protein		
1	36,52 **a**	0,5569
2	32,82 **b**	0,5569
3	29,40 **c**	0,5569
4	26,07**d**	0,5569
energy*protein		
1 1	38,37	0,7876
1 2	33,72	0,7876
1 3	29,65	0,7876
1 4	26,31	0,7876
2 1	34,67	0,7876
2 2	31,91	0,7876
2 3	29,14	0,7876
2 4	25,82	0,7876

LSD-value for energy = 1,149
LSD-value for protein = 1,626

ADDENDUM 30

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for feed conversion - period 2

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Energy	1	5,58	5,58	5,58	1,84	0,187
Protein	3	860,86	860,86	286,95	94,90	0,000
energy*protein	3	2,15	2,15	0,72	0,24	0,870
Error	24	72,57	72,57	3,02		
Total	31	941,15				

Means for feed conversion - period 2

Energy		Mean	Standard deviation
1		41,19	0,4347
2		40,36	0,4347
Protein			
1		48,28 **a**	0,6148
2		42,47 **b**	0,6148
3		37,91 **c**	0,6148
4		34,44 **d**	0,6148
energy*protein			
1	1	48,58	0,8694
1	2	43,08	0,8694
1	3	37,96	0,8694
1	4	35,15	0,8694
2	1	47,99	0,8694
2	2	41,86	0,8694
2	3	37,85	0,8694
2	4	33,72	0,8694

LSD-value for energy = 1,268
LSD-value for protein = 1,793

ADDENDUM 31

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for feed conversion - period 3

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Energy	1	10,10	10,10	10,10	1,42	0,245
Protein	3	760,21	760,21	253,40	35,67	0,000
energy*protein	3	30,84	30,84	10,28	1,45	0,245
Error	24	170,52	170,52	7,10		
Total	31	971,67				

Means for feed conversion - period 3

Energy		Mean	standard deviation
1		35,12	0,6664
2		36,25	0,6664
Protein			
1		42,47 **a**	0,9424
2		37,61 **b**	0,9424
3		33,24 **c**	0,9424
4		29,42 **d**	0,9424
energy*protein			
1	1	43,08	1,3327
1	2	37,60	1,3327
1	3	32,42	1,3327
1	4	27,40	1,3327
2	1	41,86	1,3327
2	2	37,63	1,3327
2	3	34,06	1,3327
2	4	31,44	1,3327

LSD-value for energy = 1,944
LSD-value for protein = 2,749

ADDENDUM 32

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for feed conversion – total period

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Energy	1	2,09	2,09	2,09	1,28	0,269
Protein	3	701,64	701,64	233,88	143,76	0,000
energy*protein	3	7,60	7,60	2,53	1,56	0,225
Error	24	39,04	39,04	1,63		
Total	31	750,38				

Means for feed conversion - total period

Energy		Mean	Standard deviation
1		36,12	0,3189
2		35,61	0,3189
Protein			
1		42,46 **a**	0,4509
2		37,60 **b**	0,4509
3		33,52 **c**	0,4509
4		29,88 **d**	0,4509
energy*protein			
1	1	43,41	0,6377
1	2	38,07	0,6377
1	3	33,34	0,6377
1	4	29,66	0,6377
2	1	41,50	0,6377
2	2	37,13	0,6377
2	3	33,70	0,6377
2	4	30,11	0,6377

LSD-value for energy = 0,913
LSD-value for protein = 1,317

ADDENDUM 33

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for hen weight - period 1

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Energy	1	384345	384345	384345	56,84	0,000
Protein	3	148046	148046	49349	7,30	0,001
Energy*protein	3	8893	8893	2964	0,44	0,728
Error	24	162293	162293	6762		
Total	31	703576				

Means for hen weight - period 1

Energy		Mean	standard deviation
1		3528 **a**	20,56
2		3309 **b**	20,56
Protein			
1		3329 **a**	29,07
2		3385 **ab**	29,07
3		3451 **bc**	29,07
4		3509 **c**	29,07
energy*protein			
1	1	3455	41,12
1	2	3471	41,12
1	3	3576	41,12
1	4	3611	41,12
2	1	3203	41,12
2	2	3300	41,12
2	3	3327	41,12
2	4	3407	41,12

LSD-value for energy = 60,01
LSD-value for protein = 84,86

ADDENDUM 34

Factor	Levels	Values			
Energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for hen weight - period 2

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Energy	1	823045	823045	823045	58,52	0,000
Protein	3	103480	103480	34493	2,45	0,088
energy*protein	3	45170	45170	15057	1,07	0,380
Error	24	337515	337515	14063		
Total	31	1309210				

Means for hen weight - period 2

Energy		Mean	standard deviation
1		3827 **a**	26,65
2		3507 **b**	26,65
Protein			
1		3611	41,93
2		3623	41,93
3		3679	41,93
4		3755	41,93
energy*protein			
1	1	3822	59,29
1	2	3735	59,29
1	3	3858	59,29
1	4	3894	59,29
2	1	3400	59,29
2	2	3511	59,29
2	3	3500	59,29
2	4	3616	59,29

LSD-value for energy = 86,54
LSD-value for protein = 122,38

ADDENDUM 35

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for hen weight - period 3

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Energy	1	1624052	1624052	1624052	39,93	0,000
Protein	3	239420	239420	79807	1,96	0,147
Energy*protein	3	124406	124406	41469	1,02	0,401
Error	24	976126	976126	40672		
Total	31	296126				

Means for hen weight - period 3

Energy		Mean	standard deviation
1		4095 **a**	50,42
2		3644 **b**	50,42
Protein			
1		3777	71,30
2		3821	71,30
3		3872	71,30
4		4007	71,30
energy*protein			
1	1	4097	100,84
1	2	4017	100,84
1	3	4108	100,84
1	4	4157	100,84
2	1	3457	100,84
2	2	3625	100,84
2	3	3637	100,84
2	4	3857	100,84

LSD-value for energy = 147,17
LSD-value for protein = 208,13

ADDENDUM 36

Factor	Levels	Values			
energy	2	1	2		
protein	4	1	2	3	4

Analysis of Variance for hen weight – total period

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Energy	1	1624052	1624052	1624052	39,93	0,000
Protein	3	239420	239420	79807	1,96	0,147
Energy*protein	3	124406	124406	41469	1,02	0,401
Error	24	976126	976126	40672		
Total	31	296126				

Means for hen weight – total period

Energy		Mean	standard deviation
1		4095 **a**	50,42
2		3644 **b**	50,42
Protein			
1		3777	71,30
2		3821	71,30
3		3872	71,30
4		4007	71,30
energy*protein			
1	1	4097	100,84
1	2	4017	100,84
1	3	4108	100,84
1	4	4157	100,84
2	1	3457	100,84
2	2	3625	100,84
2	3	3637	100,84
2	4	3857	100,84

LSD-value for energy = 80,76
LSD-value for protein = 114,21

ADDENDUM 37

The regression equation is: moisture = 162 + 0,862 x waterspace

Predictor	Coef	Stdev	t-ratio	P
Constant	161,9	104,2	1,55	0,123
Waterspace	8,86154	0,042	20,51	0,000

S = 131,6 R-sq = 76,5 % R-sq(adj) = 76,4 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	7286064	7286064	420,81	0,000
Error	129	2233564	17314		
Total	130	9519628			

ADDENDUM 38

The regression equation is: moisture = 72,4 + 0,684 x fat

Predictor	Coef	Stdev	t-ratio	P
Constant	72,4243	0,6254	115,81	0,000
fat	-0,68421	0,03273	-20,1	0,000

S = 1,214 R-sq = 77,9 % R-sq(adj) = 77,7 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	644,55	644,55	437,09	0,000
Error	124	182,85	1,47		
Total	125	827,40			

ADDENDUM 39

The regression equation is: protein % = 9,55 + 0,117 x waterspace %

Predictor	Coef	Stdev	t-ratio	P
Constant	9,5534	0,9210	10,37	0,000
Waterspace	0,11691	0,01426	8,20	0,000

S = 0,7374 R-sq = 36,3 % R-sq(adj) = 35,8 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	36,572	36,572	67,26	0,000
Error	118	64,167	0,544		
Total	119	100,739			

ADDENDUM 40

The regression equation is: fat % = 49,1 + 0,471 x waterspace %

Predictor	Coef	Stdev	t-ratio	P
Constant	49,093	2,698	18,19	0,000
Waterspace	-0,47060	0,04182	-11,25	0,000

S = 2,344 R-sq = 50,5 % R-sq(adj) = 50,1 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	695,63	695,63	126,63	0,000
Error	124	681,17	5,49		
Total	125	1376,80			

ADDENDUM 41

The regression equation is: g fat = 246 + 0,657 x predicted g fat

Predictor	Coef	Stdev	t-ratio	P
Constant	246,50	27,33	9,02	0,000
Predicted fat	0,65674	0,03537	18,57	0,000

S = 92,70   R-sq = 72,6 %   R-sq(adj) = 72,4 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	2962435	2962435	344,76	0,000
Error	130	1117072	8593		
Total	131	4079506			

ADDENDUM 42

The regression equation is: g fat = -699 + 0,374 x hen weight

Predictor	Coef	Stdev	t-ratio	P
Constant	-698,91	75,00	-9,32	0,000
Hen Weight	0,37379	0,01931	19,36	0,000

S = 116,5   R-sq = 74,4 %   R-sq(adj) = 74,2 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	5084187	5084187	374,78	0,000
Error	129	1749978	13566		
Total	130	6834165			

ADDENDUM 43

The regression equation is: Hen day production = 56 - 0,0735 x excess energy

Predictor	Coef	Stdev	t-ratio	P
Constant	56,889	0,9281	61,29	0,000
Predicted fat	-0,0735	0,02257	-3,25	0,017

S = 1,476 R-sq = 63,8 % R-sq(adj) = 57,8 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	23,083	23,083	10,59	0,017
Error	6	13,074	2,179		
Total	7	36,157			

ADDENDUM 44

The regression equation is: weight gain = -21,8 + 4,20 x excess energy

Predictor	Coef	Stdev	t-ratio	P
Constant	-21,79	72,96	-0,30	0,775
Hen Weight	4,202	1,433	2,93	0,026

S = 43,70 R-sq = 58,9 % R-sq(adj) = 52 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	16410	16410	8,59	0,026
Error	6	11456	1909		
Total	7	27865			

ADDENDUM 45

The regression equation is: egg weight = 60,4 + 0,0482 x excess energy

Predictor	Coef	Stdev	t-ratio	P
Constant	60,371	2,165	27,89	0,000
Predicted fat	0,04818	0,03527	1,37	0,221

S = 1,103 R-sq = 23,7 % R-sq(adj) = 11 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	2,270	2,270	1,87	0,221
Error	6	7,297	1,216		
Total	7	9,566			

ADDENDUM 46

The regression equation is: chicks = 2,69 - 0,00548 x excess energy

Predictor	Coef	Stdev	t-ratio	P
Constant	2,69247	0,06304	42,71	0,000
Hen Weight	-0,00547	0,001533	-3,57	0,012

S = 0,1003 R-sq = 68 % R-sq(adj) = 62,7 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0,12827	0,12827	12,76	0,012
Error	6	0,06031	0,01005		
Total	7	0,18859			

ADDENDUM 47

The regression equation is: egg output = 44,7 + 0,00671 x excess lysine

Predictor	Coef	Stdev	t-ratio	P
Constant	44,6562	0,3568	125,14	0,000
Predicted fat	0,006707	0,002334	2,87	0,028

S = 0,9491 R-sq = 57,9 % R-sq(adj) = 50,9 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	7,4421	7,4421	8,26	0,028
Error	6	5,4053	0,9009		
Total	7	12,8474			

ADDENDUM 48

The regression equation is: egg output = 38,1 + 0,00505 x excess lysine

Predictor	Coef	Stdev	t-ratio	P
Constant	38,1283	0,2992	127,45	0,000
Hen Weight	0,005045	0,002087	2,42	0,052

S = 0,7911 R-sq = 49,3 % R-sq(adj) = 40,9 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	3,6571	3,6571	5,84	0,052
Error	6	3,7547	0,6258		
Total	7	7,4118			

ADDENDUM 49

The regression equation is: egg weight = 63 + 0,00492 x excess lysine

Predictor	Coef	Stdev	t-ratio	P
Constant	63,0299	0,3812	165,36	0,000
Predicted fat	0,004915	0,002659	1,85	0,114

S = 1,008 R-sq = 36,3 % R-sq(adj) = 25,7 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	3,471	3,471	3,42	0,114
Error	6	6,095	1,016		
Total	7	9,566			