

DETERMINATION OF THE NUTRIENT REQUIREMENTS OF BREEDING OSTRICHES

by

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at

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Department of Animal Sciences
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Date: *March 2010*

Pectora roburant cultus recti

DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work and that I have not previously in its entirety or in part submitted it for obtaining any other qualification.

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Abstract

Title: Determination of the nutrient requirements of breeding ostriches
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The nutrient requirements for breeding ostriches are currently not well-defined. Quantification of the nutrient requirements will improve the financial wellbeing of the industry. A study of the growth of the reproductive organs and liver, together with various production studies, were therefore undertaken in order to gain knowledge about the nutrition of breeding ostriches, thereby quantifying the nutrient requirements of breeding ostriches.

Various studies were conducted to determine the influence of dietary protein, amino acids and energy on production levels of breeding ostriches.

In a first study, five diets, varying in crude protein (CP) but with a constant energy content of 9.2 MJ ME/kg feed, were provided at a feed intake level of 2.5 kg/bird/day. The dietary CP levels were 7.5%, 9.1%, 10.8%, 12.3% and 14.0%. No differences ($P>0.05$) between treatments (total eggs per female per season) were found for number of unfertilized eggs (eggs per female per season; 8.9 ± 0.8), dead-in-shell chicks (8.0 ± 0.5), number of chicks hatched (19.1 ± 1.1) and change in mass of females (-16.2 ± 1.6 kg). A tendency was observed for a difference in total egg production (mean and standard error; 39.1 ± 3.6 ; $P=0.08$). The 12.3% CP diet caused the lowest ($P<0.05$) change in live mass (-3.8 ± 2 kg) for male birds. No interaction ($P>0.05$) occurred between the genotype of the bird and the dietary protein concentration for both egg and chick production.

In a second study, six diets varying in ME (MJ ME/kg feed), were provided at an average feed intake level of 3.4 kg/bird/day. The levels were 7.5, 8.0, 8.5, 9.0, 9.5 and 10.0 MJ ME/kg feed respectively. No differences ($P>0.05$) were observed for total eggs produced per female per season (44.8 ± 7.8), number of chicks hatched (15.4 ± 4.1),

number of infertile eggs (11.5 ± 3.8), number of dead-in-shell eggs (12.1 ± 3.2) and change in mass of females (10.7 ± 3.6 kg). Males increased linearly ($y = 2.4x + 2.45$; $R^2 = 0.09$; $P < 0.05$) in live mass as the dietary energy content increased. Two eggs per diet per month were analyzed for crude protein, crude fat and trace elements, and one egg per diet per month was analyzed for fatty acid composition. Eggs from the first and last month of the season were subjected to amino acid analysis. Analysis of variance showed no difference in crude protein and fat ($P > 0.05$) content of eggs between the experimental diets, as well as for the calcium content of eggshells. The proline content differed ($P < 0.05$) between the diets. The C18:3n-3 (linoleic acid) content of the eggs increased ($P < 0.05$) amongst the dietary treatments. Crude protein, fat and C18:3n-3 content in eggs increased ($P < 0.05$) for the number of the egg in the laying cycle.

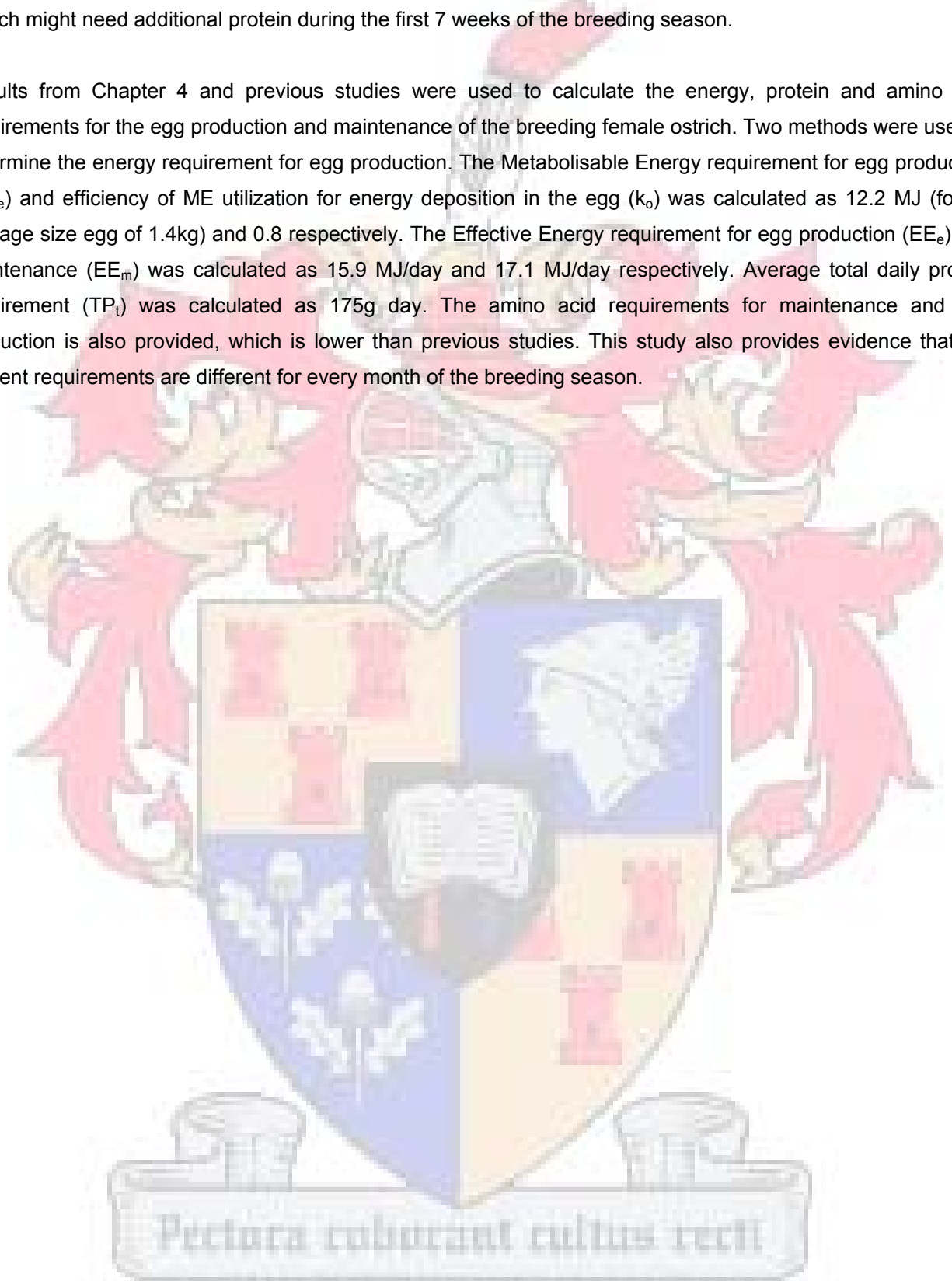
In a third study, the feed intake of breeding ostriches, as affected by dietary energy content was investigated. Average feed intake (kg feed/bird/day) was not affected ($P > 0.05$) at any dietary energy level when levels of 8.0, 8.7, 9.4, 10.1, 10.8 and 11.5 MJ ME/kg feed were provided. The mean and standard error was 3.7 ± 0.2 kg.

The production of breeding female ostriches was not influenced by dietary ME and protein at these feed intake levels. Ostrich birds do not have the ability to regulate their feed intake at any dietary energy level as used in this study. The amount of nutrients deposited in the eggs had no influence on the reproductive efficiency of the breeding female ostrich. The experiments also revealed that female breeding ostriches were independent of dietary energy and protein as used in this study for the mean frequency of egg laying at various dietary protein and energy levels ($P > 0.05$).

In a fourth study, the growth and development of the reproductive organs of female birds at the onset of the breeding season were investigated. The amount of nutrients needs to be determined in order to support the growth of the reproductive organs during the breeding season, due to the fact that these organs are linked to egg production. It was thus necessary to investigate whether the reproductive organs grew and developed during a season. The first slaughter interval was conducted at the start of the breeding season. The ovary, oviduct and liver were collected, weighed after each slaughter and analyzed. Ovary and oviduct were analyzed for crude protein and fat. No differences ($P > 0.05$) were observed between the different slaughter intervals for the mass, crude protein and fat content of both organs. No trend ($P > 0.05$) in the weight of the oviduct could be observed over the 49-day period, this weight being highly correlated with body weight; whereas the ovary weight tended to be correlated with the time after the onset of the breeding period, although the variation in weights, both within and between weighings, was very high. The variation in the weight of the ovary probably reflects differences in the laying pattern of individuals. The number of follicles were not affected ($P > 0.05$) by the number of days after mating. Livers were assessed for crude protein and fat, but no difference ($P > 0.05$) was detected between the intervals, but the weight difference amongst the slaughter intervals was significant ($P < 0.05$), suggesting that the ostriches used liver reserves to supplement nutrients that obtained from the diet for the development of the reproductive organs. This data will be used in an optimising model (Brand & Gous, 2006) to

predict the nutrient requirements of female breeding ostriches. This study suggests that the female breeding ostrich might need additional protein during the first 7 weeks of the breeding season.

Results from Chapter 4 and previous studies were used to calculate the energy, protein and amino acid requirements for the egg production and maintenance of the breeding female ostrich. Two methods were used to determine the energy requirement for egg production. The Metabolisable Energy requirement for egg production (ME_e) and efficiency of ME utilization for energy deposition in the egg (k_o) was calculated as 12.2 MJ (for an average size egg of 1.4kg) and 0.8 respectively. The Effective Energy requirement for egg production (EE_e) and maintenance (EE_m) was calculated as 15.9 MJ/day and 17.1 MJ/day respectively. Average total daily protein requirement (TP_t) was calculated as 175g/day. The amino acid requirements for maintenance and egg production is also provided, which is lower than previous studies. This study also provides evidence that the nutrient requirements are different for every month of the breeding season.



Opsomming

Titel: Beraming van die voedingsbehoefte van broeivolstruise
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Tans heers daar onsekerheid oor die voedingsbehoefte van volstruis broeivolstruise. Kwantifisering van die voedingsbehoefte sal 'n finansiële hupstoot aan die industrie gee. 'n Groeistudie van die reproduksie-organe en lewer, tesame met 'n aantal produksie-studies, is uitgevoer om inligting oor die voedingsbehoefte van volstruis broeivoëls te versamel. Daarby is die voedingsbehoefte teoreties bereken.

'n Aantal studies was uitgevoer om die invloed van dieë proteïen en aminosure en energie op produksie-data te bepaal.

Eerstens is vyf diëte, wisselend in ru-proteïen (RP) en beperk tot 'n inname van 2.5 kg/voël/dag, aan broeivolstruise gevoer. Die RP van elke dieët was 7.5%, 9.1%, 10.8%, 12.3% en 14.0%. Die energiewaarde van die voer is konstant by 9.2 MJ ME/kg voer gehou. Geen verskille ($P>0.05$) was tussen die behandelings waargeneem vir aantal geil eiers (totale eiers geproduseer per voël per seisoen; 8.9 ± 0.8), aantal dood-in-dop (8.0 ± 0.5), aantal kuikens (19.1 ± 1.1) en verandering in massa van wyfies (-16.2 ± 1.6 kg) nie. 'n Neiging ($P=0.08$) is wel waargeneem vir totale aantal eiers geproduseer. Die gemiddelde en standaard fout was 39.1 ± 3.6 . Die 12.3% dieët het tot die laagste verandering ($P<0.05$) in lewendige massa (-3.8 ± 2 kg) vir die mannetjies gelei. Geen interaksie ($P>0.05$) was tussen die genotipe en dieë proteïen konsentrasie vir beide eier- en kuikenproduksie opgemerk nie.

In 'n tweede studie is ses diëte, variërend in ME (MJ ME/kg voer), by 'n gemiddelde tempo van 3.4 kg/voël/dag gevoer. Die verskillende ME-vlakke was 7.5, 8.0, 8.5, 9.0, 9.5 en 10.0 MJ ME/kg voer. Geen betekenisvolle verskille ($P>0.05$) is vir totale eiers geproduseer per voël per seisoen (44.8 ± 7.8), aantal kuikens uitgebroei (15.4 ± 4.1), aantal geil eiers (11.5 ± 3.8), aantal dood-in-dop eiers (12.1 ± 3.2) en massa verandering van wyfies

(10.7±3.6kg) opgemerk nie. Die mannetjies het toegeneem in liggaamsmassa ($P<0.05$) soos daar 'n toename was in die energievlak van die dieët. Twee eiers per dieët per maand is vir ru-proteïen, vet en spoorelemente, en een eier per dieët per maand vir vetsure ontleed. Eiers van die eerste en laaste maand van die seisoen is ontleed vir aminosure. Analise van variansie het aangetoon dat daar geen verskille ($P>0.05$) bestaan vir die ru-proteïen en vetinhoud van die eiers by die verskillende eksperimentele diëte, asook die kalsiuminhoud van die eierdoppe. Prolien vlakke het tussen die diëte verskil ($P<0.05$). Die C18:3n-3 (linoleïensuur) inhoud van die eiers het verskil ($P<0.05$) tussen die dieët behandelings. Vir die hoeveelste eier in die lê siklus het die ru-proteïen-, vet- en C18:3n-3 inhoud van die eiers verhoog ($P<0.05$).

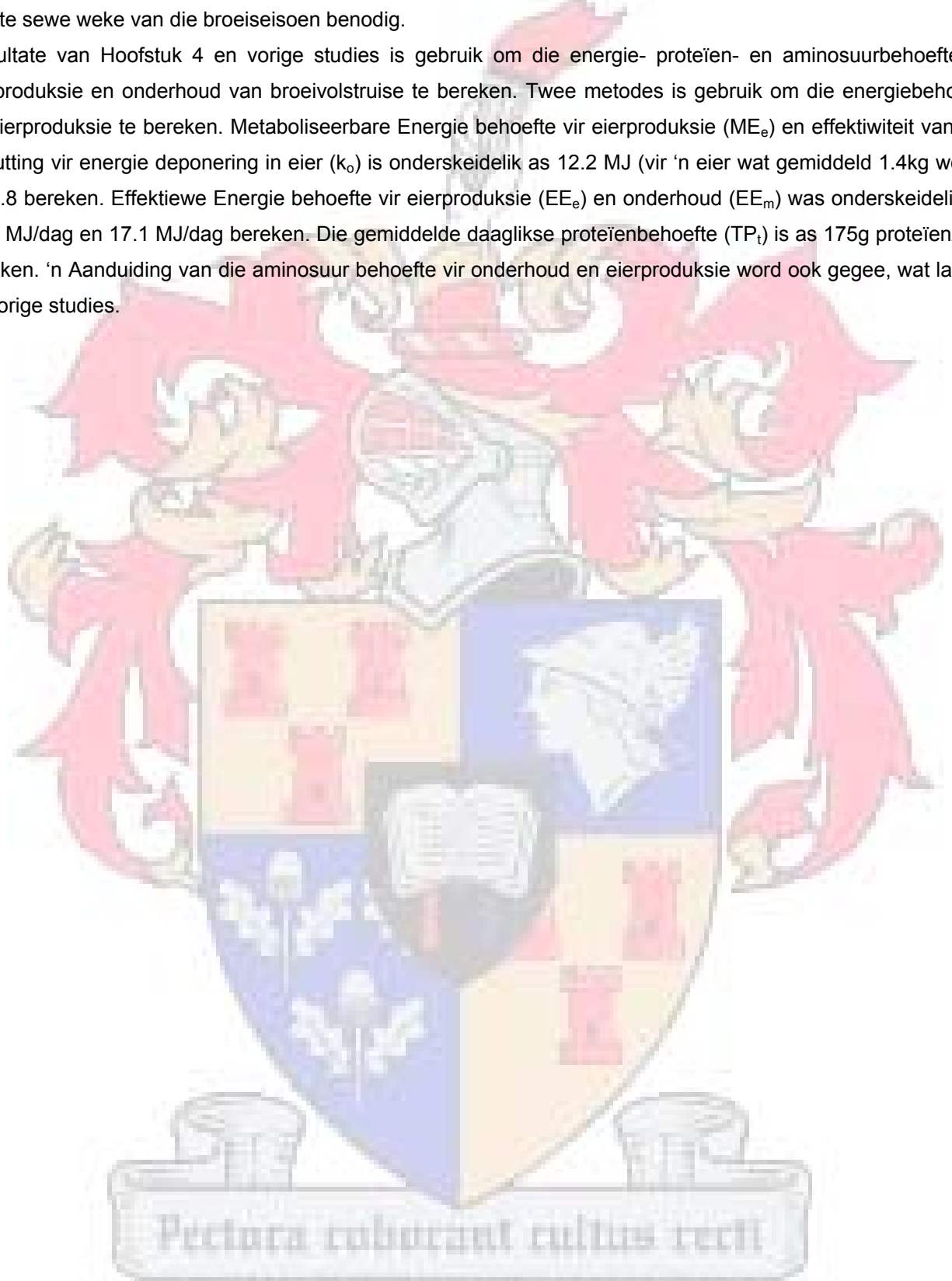
In 'n derde studie is ondersoek ingestel na die voerinname van die broeivolstruise soos moontlik beïnvloed deur die energievlak van die dieët. Gemiddelde voerinname (kg voer/voël/dag) is nie ($P>0.05$) deur die verskillende dieët energie vlakke van 8.0, 8.7, 9.4, 10.1, 10.8 en 11.5 MJ ME/kg voer beïnvloed nie. Die gemiddelde en standaardfout was 3.7 ± 0.2 kg.

Die produksie van broeivolstruise nie deur verskillende dieëtvlakke van proteïen en energie by vlakke soos gevoer in hierdie studie geraak nie. Broeivolstruise in hierdie studie het nie die vermoë gehad om hul voerinname te beheer by enige dieët energievlak soos gebruik nie. Die aantal nutriënte wat in die eiers neergelê is, het geen bydrae tot die reproduksievermoë van die wyfie gehad nie. Die studie het verder bewys dat die gemiddelde frekwensie van eier-lê by wyfies onafhanklik was by dieët-energie en -proteïenvlakke ($P>0.05$) soos in hierdie studie gebruik.

In 'n vierde studie is die groei en ontwikkeling van die reproduksie-organe van die wyfies bestudeer tydens die aanvang van die broeiseisoen. Die hoeveelheid of konsentrasie van voedingstowwe moes bepaal word om die groei van die reproduksie-organe te ondersteun tydens die broeiseisoen, omdat hierdie organe aan eierproduksie gekoppel is. 'n Studie is derhalwe uitgevoer om te bepaal tot watter mate die reproduksie organe groei en ontwikkel tydens die broeiseisoen. Die eerste slagting is uitgevoer op die dag van afkamp. Die ovaria, ovidukt en lewer is versamel, geweeg en ontleed. Die ovaria en ovidukt is ontleed vir ru-proteïen en vet. Geen verskille ($P>0.05$) is tussen die verskillende slagtings vir die gewig, ru-proteïen en vetinhoud vir beide organe opgemerk nie. Geen betekenisvolle tendens in die gewig van die ovidukt is waargeneem oor die 49-dae periode nie, maar die gewig was hoogs gekorreleerd met liggaamsmassa. Ovaria-gewig het geneig om gekorreleerd te wees met die aantal dae na afkamp. Variasie binne en buite die gewigte was baie hoog. Die aantal follikels teenwoordig is nie beïnvloed ($P>0.05$) deur die aantal dae na paring. Die lewers is ontleed vir ru-proteïen en vet, maar geen verskille ($P>0.05$) is tussen die intervalle opgemerk nie, maar die gewigte van dag 0 en 49 na paring het verskil ($P<0.05$). Dit kan aangevoer word dat die voëls moontlik lewer reserwes gebruik het om die voedingstowwe van die dieët te supplementeer vir die ontwikkeling van die reproduksie-organe. Data uit hierdie studie kan gebruik word in 'n optimiseringsmodel (Brand & Gous, 2006) om die voedingsbehoefes van

broeivolstruise te bepaal. Hierdie studie beveel aan dat die broeiwyfie moontlik addisionele proteïen tydens die eerste sewe weke van die broeiseisoen benodig.

Resultate van Hoofstuk 4 en vorige studies is gebruik om die energie- proteïen- en aminosuurbehoefte vir eierproduksie en onderhoud van broeivolstruise te bereken. Twee metodes is gebruik om die energiebehoefte vir eierproduksie te bereken. Metaboliseerbare Energie behoefte vir eierproduksie (ME_e) en effektiwiteit van ME benutting vir energie deponering in eier (k_o) is onderskeidelik as 12.2 MJ (vir 'n eier wat gemiddeld 1.4kg weeg) en 0.8 bereken. Effektiewe Energie behoefte vir eierproduksie (EE_e) en onderhoud (EE_m) was onderskeidelik as 15.9 MJ/dag en 17.1 MJ/dag bereken. Die gemiddelde daaglikse proteïenbehoefte (TP_t) is as 175g proteïen/dag bereken. 'n Aanduiding van die aminosuur behoefte vir onderhoud en eierproduksie word ook gegee, wat laer is as vorige studies.



Chapter 1

Literature Review

GENERAL INTRODUCTION

South Africa produces about 60% of the world's ostrich products (South African Ostrich Business Chamber, 2002). Estimated export meat production for 2008 was approximately 3700 tons, which is lower than the demand of 4000 tons (Coleman, 2008). It is therefore an invaluable part of the livestock population in South Africa.

Reliable nutritional data for ostriches are scarce. Several attempts have been made to define the nutrient requirements of ostriches (du Preez, 1991; Cilliers, 1994; Brand & Gous, 2006). A lack of nutritional data may be the reason for poor egg production levels in breeding ostriches (Brand *et al.*, 2003). Nutritional values extrapolated from data collected from chickens have been used in the past to calculate nutrient requirements of ostriches, but cannot always be used for mature breeding birds. A scientific approach is needed to obtain the nutrient requirements of breeding ostriches, in order to ensure the financial wellbeing of the industry. A better understanding of the breeding ostrich's feed requirements will accordingly be of immense value to the industry.

There are still big challenges facing the industry, especially with the reproduction and breeding of ostriches. Infertile eggs and embryonic deaths, resulting in a low hatchability and the high mortality of ostrich chicks, are major problems in the industry. In addition, the reproductive performance of breeding ostriches is highly variable (Bunter *et al.*, 2001). Non-genetic and genetic factors are possibly responsible for differences in reproduction.

CURRENT PROBLEMS ENCOUNTERED IN THE INDUSTRY

INFERTILE EGGS

Infertile eggs may be a result of the infertility of males and obesity in females (Smith *et al.*, 1995b). Obesity is a significant cause of lower egg production levels (Irons, 1995). Vitamin A, E and selenium deficiencies are responsible for infertility in other avian species. Behavioural problems, for example a failure to copulate, also contribute to reproduction problems like lower egg production levels (Hicks, 1993). In addition, males are over-consuming high calcium and energy layer diets, resulting in overweight males with poor sperm production. The reason for the poor sperm production may be the low zinc availability during the consumption of high calcium

diets (Smith *et al.*, 1995b). The age of males can also contribute to poor fertility of eggs, according to Bunter *et al.* (2001).

Irons (1995) stated the following apparent causes of poor fertility in ostriches:

- Males lagging behind females at onset of breeding season
- Incompatibility between a mating male and female
- Lack of libido in males
- Infertility of males and females
- Immaturity
- Exhaustion of males during season
- Nutrition, especially obesity

EMBRYONIC DEATHS

According to Smith *et al.* (1995b), the causes for embryonic deaths in the Little Karoo area (situated in the Western Cape province of South Africa) are: inadequate heat distribution in incubators, the inability to dispose of excess moisture in incubators, poor ventilation with CO₂ levels exceeding 0.5%, incorrect egg-turning procedures, and poor storage facilities for eggs before incubation. Gonzalez *et al.* (1999) stated that low hatchability of eggs can be ascribed to the insufficient loss of weight during the incubation period of eggs. Hicks (1993) reported poor nutrition of the hen, toxins, improper egg storage and incubation methods, as causes of embryonic deaths. Intra-shell embryonic death and low hatchability, are a result of the failure of the two roles that the cuticle of the egg performs (Brown *et al.*, 1996; Huchzermeyer, 1996). Shell ultrastructural abnormalities cause low hatchability and hatching trauma (Richards *et al.*, 2000).

In a study by Brown *et al.* (1996) it was found that malpositioning and severe oedema were the most prevalent symptoms of dead-in-shell embryos. The former is caused from wrong setting of eggs or inadequate turning. Severe oedema is correlated significantly with the amount of water loss from the eggs. Inadequate turning causes retarded growth of the area vasculosa, reduction in the formation of sub-embryonic fluid and growth of the chorioallantoic membrane (limiting oxygen uptake), reduced albumen (protein) uptake and malposition (Tullett & Deeming, 1987; Deeming, 1989a,b). Deficiency or excess of vitamin A in the parent birds can also result in malposition (Angel, 1993). On the other hand, Philbey *et al.* (1991) could not produce evidence that selenium, vitamin E or vitamin A, causes poor hatchability. Other symptoms for embryonic deaths reported by Brown *et al.* (1996) are: bacterial infections, myopathy, deformities, other and unknown factors. Anasarca,

myopathy and malpositioning as symptoms for embryonic deaths and low hatchability were identified by Philbey *et al.* (1991).

The microbial spoilage of ostrich eggs is a significant problem and leads to a reduction in the hatching percentage (Deeming, 1995 & 1996a). Ostrich eggs appear to be susceptible to fungal penetration as a result of a lack of shell cuticle. According to Deeming (1995 & 1996a), nest hygiene is the simplest way to reduce the contamination of ostrich eggs. The incidence of contamination worsens as the season progresses as a result of greater spoilage of the nesting environment, changes in management associated with delayed egg collection until the next morning, or changes in shell structure through the season (Deeming, 1996b).

CHICK MORTALITY

It is a prominent fact that a high mortality rate exists among ostrich chicks. A higher survival percentage impacts positively on production and profit (Samson, 1997). A lack of functional development of the digestive tract of the chick just after hatching, is an important factor in the high mortality rates of the chick when the dependence on the yolk-sac is terminated (Terzich & Vanhooser, 1993; Button *et al.*, 1996; Verwoerd *et al.*, 1999). Samson (1997) reported that impaction, cloacal prolapse, bacterial enteritis, rolled toes, rotational deformities of the leg, slipped tendons, respiratory disorders, feather pecking and pantothenic acid deficiency are all common health disorders that affect ostrich production. In another study, omphalitis, starvation, dehydration, septicaemia and enteritis were all identified as causes of mortality (Mushi *et al.*, 2004). Cloete *et al.* (2001) reported that the high levels of mortality in their study could possibly be ascribed to stress experienced by the chicks and not being capable of adapting to the rearing environment.

DIGESTIVE ANATOMY OF OSTRICHES

The ostrich is a monogastric animal and in comparison to the chicken, the ostrich has no crop, but the upper part of the oesophagus is slightly enlarged for the accumulation of food (Brand & Gous, 2006). Ostriches have a large digestive tract, characterized by spacious ceca and a long colon (Cho *et al.*, 1983), which creates a favourable environment for the fermentation of fibrous material (Brand & Gous, 2006). The anatomy of the digestive tract and its development are described in detail respectively by Bezuidenhout (1986) and Iji *et al.* (2003). Jozefiak *et al.* (2004) reviewed carbohydrate fermentation in the avian ceca, concluding that short-chain fatty acids are the highest in the cecum compared to other areas of the gastrointestinal tract. It may inhibit the growth of pathogenic organisms and provide energy-yielding substrates to the avian bird after absorption. Acetate is the major volatile fatty acid produced, and propionate and butyrate in much smaller quantities,

according to Swart (1988). The end-products of fermentation can contribute as much as 76% of the ostrich's metabolizable energy (ME) requirements. Fibrous feed has a long retention time in the digestive tract, which ensures extended times for the micro-organisms to digest the feed. Swart (1988) reported the digestibility of cell walls (NDF), hemi-cellulose and cellulose respectively as 47%, 66% and 38%. Due to their ability to utilize fiber, the possibility of grazing mature ostriches on pasture cannot be excluded (Brand, 2003).

Although the ostrich has the ability to digest fiber, the efficiency of ME utilization tended to decrease with decreased energy or increased crude fiber concentrations in the diet (Swart *et al.*, 1993). This may affect the overall utilization of diets high in crude fibre especially in young chicks.

FEEDSTUFF EVALUATION

Nutritionists in the past have used ME values of raw materials from poultry for ostrich diet formulation, although this is not recommended. Ostriches had higher TME_n (true metabolisable energy corrected for nitrogen retention) values (Cilliers, 1994, 1998; Cilliers *et al.*, 1994, 1995, 1998 a,b,c, 1999) for most common ingredients used in the diets of ostriches and higher true and apparent digestibilities of amino acids on a high protein experimental diet (Cilliers *et al.*, 1997) compared to chickens. The mean value of the true faecal digestibility of amino acids for ostriches was calculated as 0.84±0.01, compared to a value of 0.80±0.03 obtained for cockerels (Cilliers *et al.*, 1997). If the values for poultry are used, it will lead to an over-estimation of the requirements of ostriches. Cilliers & Angel (1999) stated that obesity has been observed in breeders and marked-age ostriches when formulating diets using energy values derived from poultry. Brand *et al.* (2000b) compared the metabolisable energy (ME) values of ostriches for three different diets with the ME values of pigs, poultry and ruminants. The diets differed in fiber content (low fiber, medium fiber and high fiber). Metabolisable energy (ME) value for ostriches differ significantly from those of poultry, pigs and ruminants for all three diets. Table 1.1 presents a comparison between the energy content of balanced diets with different fibre content for ostriches, poultry and pigs (Brand *et al.*, 2000b). Twenty-five percent more energy was utilized from the same feed for ostriches compared to values obtained with pigs. This relates to the ability of the ostrich to extract energy from fiber material, as reported by Swart (1988).

Progress has been made in order to find suitable and edible raw materials for ostriches. Oilseeds play an important role in the nutrition of livestock. Canola oilcake meal and full-fat canola were investigated by Brand *et al.* (2000a) as a potential protein source for ostriches. True metabolisable energy values (TME) of 13.8 MJ/kg and 22.5 MJ/kg were determined respectively for canola oilcake and full-fat canola, which is higher than the value determined for poultry. Cilliers *et al.* (1994) also found that the TME_n value for lucerne is higher for ostriches, confirming their capability to digest fiber. Lucerne is a suitable ingredient to use in the diets of ostriches due to its crude protein content (18%), crude fiber content (30%), apparent metabolisable energy

(8.9MJ/kg feed), and 50.1% dry matter digestibility (Glatz *et al.*, 2003). Table 1.2 provides the TME_n values of some raw materials for ostriches and cockerels, as determined by Cilliers *et al.* (1999). Progress like this is of great importance in order to broaden our knowledge of the nutritional requirements of ostriches. It is also needed for accurate diet formulation and to determine which raw materials are the most appropriate and the most economical to include in the rations of ostriches.

Table 1.1 Calculated Metabolisable energy content of diets for various species (Brand *et al.*, 2000b)

Diet	Ostrich (TME, MJ/kg)	Pig (ME, MJ/kg)	Poultry (TME, MJ/kg)	Ruminant (ME, MJ/kg)
Low fibre:				
Starter	5.0	12.8	16.8	13.2
Grower	14.8	12.3	14.7	12.6
Finisher	14.9	13.0	14.1	12.3
Medium fibre:				
Starter	14.1	10.4	12.3	11.4
Grower	14.0	10.4	9.7	10.1
Finisher	13.9	11.1	12.2	10.9
High fibre:				
Starter	12.0	9.8	8.7	10.0
Grower	12.8	8.8	8.2	9.6
Finisher	12.4	10.5	9.0	10.3

Table 1.2 The mean and standard error for TME_n (MJ/kg) values of different raw materials for ostriches and cockerels (Cilliers *et al.*, 1999)

Raw material	Ostriches	Cockerels
Wheat Bran	11.9 ^a	8.6 ^b
Saltbush	7.1 ^a	4.5 ^b
Common reed	8.7 ^a	2.8 ^b
Lupins	14.6 ^a	9.4 ^b
SBOCM	13.4 ^a	9.0 ^b
SFOCM	10.8 ^a	8.9 ^b
Fishmeal	15.1 ^a	14.0 ^b
Standard error	0.3	0.4

means in rows with different superscript differ significantly (P<0.05)

SBOCM: soya bean oilcake meal

SFOCM: sun flower oilcake meal



NUTRIENT REQUIREMENTS

ENERGY

Swart *et al.* (1993) calculated the energy requirement of ostriches for maintenance (ME_m) as 0.44 MJ/metabolic weight $kg^{0.75}$ /day and efficiency of ME utilization by ostriches for growth as 0.32. Cilliers *et al.* (1998c) calculation for maintenance of 7 month ostriches (0.425 MJ/empty body weight/day) is in agreement with the value of Swart *et al.* (1993), but a higher ME utilization (k_{pf}) value of 0.414 was measured. ME utilization in ostriches is quite low compared to with fowls and pigs. McDonald *et al.* (2002) for example reported a value of 0.90 and 0.85 for ME utilization by respectively for fowls and pigs while consuming a balanced diet.

Du Preez (1991) estimated the energy requirements of ostriches in 0.25 hectare breeding pens and includes the total MJ ME needed for egg production, maintenance and activity. The total MJ ME needed per day for an 110kg bird laying a 1.4kg egg according to du Preez (1991) was 23 MJ ME. Smith *et al.* (1995a) stated that the breeding female ostrich probably has an increased requirement for energy before the first egg is formed.

PROTEIN AND AMINO ACIDS

Protein and amino acid requirements were determined for growing ostriches and breeding ostriches, by Cilliers *et al.* (1998c) and du Preez (1991) respectively. Cilliers *et al.* (1998c) calculated the maintenance requirements for total protein (TP_m) and essential amino acids (AA_m) and the efficiency of the utilization of protein and amino acid retentions by a comparative slaughter technique, in conjunction with a model proposed by Emmans & Fisher (1986). Cilliers *et al.* (1998c) then estimated the dietary requirements for ostriches from seven months old, and the results were extrapolated to estimate requirements to 20 months of age.

Du Preez (1991) calculated the protein and amino acid requirements for the egg production of ostriches according to the weight of the egg and the weight of the female bird. He assumed that the breeding ostriches will lay an egg every second day and will consume 2 kg feed per day. More protein and amino acids are required to produce heavier eggs and maintained a higher body mass. Total daily protein requirements, including requirements for maintenance and egg production (1.4 kg eggs), were calculated as 210g protein. According to du Preez (1991), nutrient requirements for egg production can be estimated by using information like egg mass, frequency of egg laying and the composition of the egg. Using variables like live weight and egg mass has been used previously to determine nutrient requirements for poultry (Combs, 1968).

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It is also important to know the onset of the formation of the reproductive organs (ovary and oviduct), since this is linked to egg production and healthy reproductive performance. King (1973) demonstrated that the time it takes for follicular development in fowls is 7-8 days. The duration of this period for ostriches is unknown. It is estimated as 16 days, meaning that the breeding bird has a high requirement for nutrients 18 days before the first egg is laid (du Preez, 1991). This requirement will rise in a sigmoidal pattern, reaching a maximum 8 days before the onset of egg production. Smith *et al.* (1995a) also stated that the breeding female ostrich has a high requirement for amino acids before the first egg is formed. The requirements will be constant until a laying day is skipped. The amount of nutrients needed is not dependent on the time it takes for egg production. It is, however, dependent on the amount of nutrients deposited in the egg. Kwakkel *et al.* (1993) stated it is imperative to know when the reproductive tract develops, in order to ensure favourable nutrition at the right time for the development of these vital structures.

Bowmaker & Gous (1989) studied the growth of the liver, ovary, and oviduct before and after the onset of sexual maturity for broiler breeder pullets. The protein, lysine, methionine and tryptophan requirement of 20-30 week old broiler breeders for maintenance and growth were calculated, using a formula from Emmans & Fisher (1986). Bowmaker & Gous (1989) concluded that feeding higher protein levels during the pre-laying season is redundant, since no evidence exists that such extra protein is deposited in the body, from which the bird can draw for egg production purposes on a later stage in the laying period.

Martin *et al.* (1994) estimated the amino acid requirements of laying-type pullets during their growing period. Requirements were calculated for four functions, that is: body protein gain, body protein maintenance, feather protein gain and feather protein maintenance. Accretion of body and feather protein was accurately described by the Gompertz equation. The growth rate of the whole body was calculated by using allometric relationships to estimate other components for growth, which were summed in the end. The growth of different body components was measured by using nutritional constants which define the amount of amino acid needed for tissue formation.

The protein requirement depends on the amino acid composition of that protein and the production rate. Brand & Gous (2006) stated that the amino acid requirements of ostriches should be determined by using the chemical composition of the body and feathers in conjunction with the relative growth rates of the body and the feathers. In other words, the growth potential of body and feather protein should be characterised and described. The chemical and amino acid composition of whole ostrich carcasses (at different growth stages) were analyzed by Brand *et al.* (2005). The daily requirement for each amino acid equals the sum of each amino acid needed for the maintenance and growth of feather and body protein (Gous, 1993). In the past, amino acid requirements were determined by the concentration of that amino acid in the diet that promotes maximum growth. But this method has potential errors (Gous & Morris, 1985). The disadvantages are as follows:

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- The amino acid under study may no longer be first-limiting under high levels of supplementation. The birds might be able to respond further if the new first-limiting amino acid was added to the diet.
- Difficulty in constructing a basal diet which is low in the amino acid being studied, but adequate in all others.
- Some synthetic amino acids are expensive.

VITAMIN AND MINERAL REQUIREMENTS

Very little scientific information is available on the vitamin and mineral requirements of the breeding ostrich (Brand & Gous, 2006). Smith *et al.* (1995a) anticipated that the breeding female ostrich has an increased requirement for minerals (calcium and phosphorus) and vitamins before the first egg is formed. Cilliers & Van Schalkwyk (1994) listed the specifications during the lay period for total calcium (%), available phosphorus (%), and total sodium (%) as 2.0-2.5, 0.35-0.40 and 0.15-0.25 respectively. The supplementation of trace elements and vitamins has also been specified by Cilliers & Van Schalkwyk (1994).

Recent research by Almeida Paz *et al.* (2008) showed that long term feeding of a diet low in calcium (0.93%) may impair egg production, but feeding the diet over an eight week period is sufficient to support egg production. A dietary calcium level of 3.83% increased the bone strength of the birds, while an increased mass of the eggs were noticed (1748±180g and 1529±148g, respectively for the 3.83% and 0.93% diet.)

EFFECT OF PROTEIN AND ENERGY ON PRODUCTION

Energy and protein are the most expensive nutrients in a diet. High levels are not a necessity and may even be detrimental to the production rates of ostriches (Brand *et al.*, 2003). Williams (1994) and Deeming *et al.* (1996) indicated that inadequate dietary energy and protein levels may lead to fewer small, poor quality eggs and poor hatchlings with reduced fitness. There was also an increase in the incidence of obesity and leg injuries when rations high in energy and protein were fed to ostriches (Glatz *et al.*, 2003).

Brand *et al.* (2003) performed a study, spanning two breeding seasons, to determine whether energy and protein may have an effect on the production of female breeding ostriches. Nine different diets in each season were given to females. The females laid fewer eggs at longer intervals at the lower dietary energy level (7.5 MJ ME/kg feed at 2.5kg feed/bird), therefore fewer chicks hatched. Significantly more eggs were laid by females fed on the diets containing 8.5 and 9.5 MJ ME/kg feed, also at a daily provision of 2.5kg feed/bird. Females also tend to lose more mass on diets containing less energy. Interestingly, the different dietary protein levels had no

significant effect on the production characteristics of breeding females. This is in contrast with chickens, where protein (more specifically amino acids) is essential for egg output (Gous & Morris, 1985). The different levels of energy and protein had no effect on the mean mass of eggs laid. This study concluded that energy is the main constraint on egg production during breeding; and that a diet containing a minimum level of 8.5 MJ ME/kg DM and 105g/kg protein with a specific accompanied amino acid profile is sufficient to support production of female breeding birds.

Nutrition-related carry-over effects, from one season to the next were reported by Brand *et al.* (2002). A diet containing less than 8.5 MJ ME/kg feed, provided at 2.5kg feed/bird/day, can have an adverse effect on egg production in the following breeding season. In the study by Brand *et al.* (2002), different dietary protein levels, given in previous years had no effect on egg production, egg weight, fertility, hatchability, and initial chick mass in consecutive years of production. Different levels of dietary energy in previous years had no effect on other production parameters like body mass, initial egg weight or the percentage of infertile eggs over three months. No carry-over effects were observed for mass of females for both protein and energy levels. This phenomenon can be a result of the rest period where the birds had the opportunity to gain the lost body mass.

EFFECT OF FATTY ACIDS ON EGG COMPOSITION AND IMMUNITY

The lipids of the yolk are the primary energy source of the chick embryo, providing more than 90% of the energy requirements for development and addition of structural components for membrane biogenesis (Speake *et al.*, 1998). Utilization of the yolk sac is an imperative aspect of the development of the chick (Bertram & Burger, 1981). It also plays an important role in complementing the nutrients absorbed for rapid growth (Murakami *et al.*, 1992). The various lipids of the yolk are synthesized in the liver of the hen and transferred to the ovary for uptake by the developing oocyte (Griffin *et al.*, 1984; Walzem, 1996). Yolk contains about 6g lipid and 3g protein, which is about respectively 10% and 3% of the egg (Speake *et al.*, 1998). Freeman & Vince (1974) stated that the β -oxidation of fatty acids is the predominant pathway of energy delivering in the system. The newly hatched chick obtains most of its fatty acids from the lipids in the yolk of the egg. These fatty acids are transferred to the developing embryo during the 21-day incubation period. The diet of the hen also greatly influences the fatty acid composition of the newly hatched chick (Anderson *et al.*, 1989).

Fatty acids in the diets of avian species can affect the fatty acid composition of the yolk. Eicosapentaenoic and docosahexaenoic acid levels in egg yolk were influenced by the dietary inclusion of herring meal in laying hens (Nash *et al.*, 1995). Dietary fat, sterols and drugs also influence the cholesterol content of egg yolk (Naber, 1979). Diets formulated for ostriches in captivity may displace the egg's n-6/n-3 ratio of polyunsaturated fatty acids compared to birds in the wild environment (Surai *et al.*, 2001). Extreme changes can have fatal effects on the development of the embryo. The yolks of the eggs of wild and farmed ostriches are characterized by big

differences in fatty acid composition, particularly in linolenic acid (C18:3n-3) (Noble *et al.*, 1996). In the wild state and in chickens, linolenic acid (C18:3n-3) and linoleic acid (C18:2n-6) respectively are the predominant fatty acid. Lower n-3 fatty acids in the eggs of farmed ostriches result in lower hatchability, as observed in the study by Noble *et al.* (1996). This observation is in contrast with findings by Anderson *et al.* (1989), who observed no lower hatchability levels for poultry.

The immune response of laying hens can be boosted by the manipulation of dietary fatty acids (Wang *et al.*, 2000a,b). Immunoglobulins are found in the yolk of the egg, providing passive immunity to the newly hatched chick. These proteins are transferred from the blood of the avian to the egg yolk (Rose & Orlans, 1981). Wang *et al.* (2000a) reported a higher concentration of immunoglobulins in the egg yolk by feeding laying hens a diet rich in n-3 polyunsaturated fatty acids. The effect of these fatty-acids appears to be dose-dependent (Wang *et al.*, 2000b). Therefore, dietary fatty acids can possibly have an influence on the immune system of the bird (Calder, 1999; Wang *et al.*, 2002). In addition, the egg contains other immune factors (carotenoids, immunoglobulins, lysozymes, etc.) which might influence offspring fitness through effects on the immune response of the embryo or chick (Williams, 2005).

DEVELOPMENT OF REPRODUCTIVE ORGANS

The annual breeding season in South Africa starts in June and ends January the following year. Ostriches are seasonal breeders and respond to a change in photoperiod. An increase in the photoperiod initiate gonadal maturation and reproduction (Dawson *et al.*, 1986; Foster *et al.*, 1987). Lambrechts (2004) discussed the photoperiod-dependent breeding strategy of ostriches.

The reproductive organs of the ostrich hen consist of the ovary and oviduct. Only the left ovary and oviduct develop (Duerden, 1912; Fowler, 1991). The ovary is situated above the oviduct. The former consist of follicles of different stages of development and resembles a bunch of grapes (Soley & Groenewald, 1999). Twelve to sixteen ova attain maturity during the breeding season (MacAlister, 1864; Duerden, 1912). No information is available about the timing of ovulation and duration of egg passage in the oviduct (Irons, 1995). Soley & Groenewald (1999) estimated 48 hours for egg passage, since a hen lays one egg every second day.

The oviduct consists of the infundibulum, magnum, isthmus, uterus and vagina (Duerden, 1912; Muwasi *et al.*, 1982) and is responsible for the production of large amounts of protein and other constituents of the egg (Muwasi *et al.*, 1982). The magnum and isthmus are involved in the formation and secretion of proteins like albumen and keratin (Richardson, 1935; Romanoff & Romanoff, 1949; Yu *et al.* 1972). Compared with the magnum and isthmus, the infundibulum, uterus and vagina are not actively involved in protein secretion (Richardson, 1935; Sturkie, 1965; Yu *et al.*, 1972). The infundibulum is the region receiving the ovulated ova and

where fertilization takes place, about 15 minutes after ovulation in the chicken. In the magnum, thick albumen is added to the yolk. Inner and outer shell membranes are added in the isthmus. Water is absorbed into the albumen and the shell is added in the uterus. (Hicks, 1993). The vagina contains sperm tubules (Bezuidenhout *et al.*, 1995) and appears to have no secretory function (Griffin *et al.*, 1984). Palmer & Guilette Jr. (1991) reported the effects of the oviductal proteins on embryonic development. The biological properties of albumen proteins can be classified into antimicrobial, nutritive, support and cushioning, and water-binding proteins.

A change in the size of the avian oviduct occurs during a reproductive cycle (Yu & Marquardt, 1974), which is regulated by gonadal hormones (Brandt & Nalbandov, 1956; O'Malley *et al.*, 1969; Oka & Schimke, 1969; Palmiter & Wrenn, 1971; Yu & Marquardt, 1973). Development of the oviduct is influenced by endogenous or exogenous gonadal hormones and nutrition (Brown & Jackson, 1959). Diet and food intake are also factors that can influence organ size and function (Dykstra & Karasov, 1992; Geluso & Hayes, 1999). A deficit in folic acid can retard the growth of the oviduct in 21-25 day old chicks (Hertz & Sebrell, 1944). On the other hand, Scott *et al.* (1969) conveyed that excess fat that is deposited in adipose tissue surrounding the reproductive organs will influence egg production. Yu & Marquardt (1974) investigated the hyperplasia and hypertrophy of the oviduct from the chicken during the developing, laying and regressing stage. The oviduct grew rapidly eight weeks before the onset of the laying cycle. Maximum weight was attained in the middle and later period of the laying cycle. Cell numbers also increased as growth progressed during development until the onset of lay. The dry cell mass of the magnum and isthmus changed to a similar extent, while the dry cell mass of the infundibulum, uterus and vagina were of a lesser extent. Yu & Marquardt (1974) stated that the growth patterns of the different oviduct parts during a reproductive cycle are due to changes in protein secretion. Changes can occur over a short timescale (Gaunt *et al.*, 1990; Piersma *et al.*, 1999). During egg production, the reproductive organs of female starlings undergo rapid and large changes in mass (Vezina and Williams, 2003). The rapid growth of the oviduct confirms that this organ is an energetically expensive organ. Williams & Ames (2004) added that the cost of oviduct function contributes to the cost of laying an egg. Birds with a larger oviduct might be able to produce better quality eggs (Williams, 1994), due to a positive relationship between the albumen content of eggs and oviduct mass (Christians & Williams, 1999). This might prove useful in enhancing the fitness of offspring in terms of growth (Williams, 1994; Finkler *et al.*, 1998). The mother might transfer immunoglobulins and antibacterial factors to the offspring in the egg albumen (Saino *et al.*, 2001; 2002). Oviduct size or function might also have an effect on bringing about these maternal results (Williams & Ames, 2004).

GROWTH CURVES FOR OSTRICHES

The growth of animals follows a mathematical curve like the Gompertz growth curve. Several studies have been performed to describe the growth of ostriches and to find parameters for the Gompertz equation (du Preez *et al.*, 1992; Cilliers *et al.*, 1995; Brand & Gous, 2006; Gous & Brand, 2008; Kritzinger *et al.*, 2009). This curve

describes the genetic potential of the bird (Emmans & Fisher, 1986) and a flock of similar birds under non-limiting conditions (du Preez *et al.*, 1992). Emmans (1989) stated that the curve has multiple uses in production and research and can be used as a tool to measure the quality of management and feeding against the potential growth of the animal, and when statistical comparisons are made amongst birds (Cilliers *et al.*, 1995). This is useful for the selection of progeny for breeding purposes in the future. Wellock *et al.* (2004) examined the Gompertz function and concluded that the model is a suitable descriptor of potential growth due to its simplicity, accuracy and ease of application. The equation, with its parameters, is as follows (Winsor, 1932; Emmans, 1989):

$$y = ke^{-e^{-a-bx}}$$

or

$$w = ce^{(-e^{-d(t-t^*)})}$$

y = mass in kg at time t

c = mass at maturity

d = rate of maturing

t* = age in days at which daily growth rate reaches its maximum value

AIM OF THE STUDY

It is evident from this chapter that many challenges exist in the industry and that the knowledge of the nutrient requirements of breeding ostriches is inconclusive. Modelling is a tool that provides a solution to this problem. Ferguson *et al.* (1994) stated that the success of using a model for growth is the ability to calculate the nutritional and environmental requirements of the animal that are needed for potential growth and to predict the consequences of deviations from these optimum conditions. Thus the nutrients required for different periods of growth can be determined, and this leads to more effective financial and management decisions.

The aim of this study was to determine the nutrient requirements for the development of the reproductive organs, maintenance and egg production in female breeding ostriches by means of modelling, and to assess feed intake as affected by the energy content of the feed.

REFERENCES

- Almeida Paz, I.C.L., Mendes, A.A., Balog, A., Komiyama, C.M., Almeida, I.C.L. & Milbradt, E.L., 2008. Bone and egg quality of breeder ostriches fed a maintenance diet (low calcium) and a layer diet (high calcium). 4th Ratite Sci. Sym, 29 June - 4 July 2008, Brisbane, Australia
- Anderson, G.J., Connor, W.E., Corliss, J.D. & Lin, D.S., 1989. Rapid modulation of the docosahexaenoic acid levels in the brain and retina of the newly hatched chicks. *J. Lipid Res.* 30, 433-441
- Angel, C.R., 1993. Research update. Age changes in the digestibility of nutrients in ostriches and nutrient profiles of the hen and the chick. *Proc. Assoc. Avian Vet.* pp. 275-281
- Bertram, B.C.R. & Burger, A.E., 1981. Aspects of incubation in ostriches. *Ostrich.* 52, 36-43
- Bezuidenhout, A.J., 1986. The topography of the thoraco-abdominal viscera in the ostrich (*Struthio camelus*). *Onderstepoort J. Vet. Res.* 53, 111-117
- Bezuidenhout, A.J., Soley, J.T., Groenewald, H.B. & Burger, W.P., 1995. Sperm-storage tubules in the vagina of the ostrich (*Struthio camelus*). *Onderstepoort J. Vet. Res.* 62, 193-199
- Bowmaker, J.E. & Gous, R.M., 1989. Quantification of reproductive changes and nutrient requirements of broiler breeder pullets at sexual maturity. *Br. Poult. Sci.* 30, 663-675
- Brand, T.S., 2003. The potential of ostriches to utilize high fibre diets. *AFMA Matrix.* September 2003. pp. 31-32
- Brand, T.S., de Brabander, L., Van Schalkwyk, S.J., Pfister, B. & Hayes, J.P., 2000a. The true metabolisable energy content of canola oilcake meal and full-fat canola seed for ostriches (*Struthio camelus*). *Br. Poult. Sci.* 41, 201-203
- Brand, T.S., Gous, R.M., Kruger, A.C. & Aucamp, B.B., 2005. The chemical and amino acid composition of whole ostrich carcasses at different growth stages. *Proc. 3rd Int. Rat. Sci. Symp.* 14-16 October 2005, Madrid, Spain
- Brand, T.S. & Gous, R.M., 2006. Feeding Ostriches. In: *Feeding in domestic vertebrates: From structure to behaviour.* Ed. Bels, V., CAB International, Wallingford, England. pp. 136-155
- Brand, T.S., van der Merwe, J.P., Salih, M. & Brand, Z., 2000b. Comparison of estimates of feed energy obtained from ostriches with estimates obtained from pigs, poultry and ruminants. *S. Afr. J. Anim. Sci.* 30 Suppl 1, 13-14
- Brand, Z., Brand, T.S. & Brown, C.R., 2002. The effect of dietary and protein levels during a breeding season of ostriches (*Struthio camelus domesticus*) on production the following season. *S. Afr. J. Anim. Sci.* 32, 226-230
- Brand, Z., Brand, T.S. & Brown, C.R., 2003. The effect of dietary energy and protein levels on production in breeding female ostriches. *Br. Poult. Sci.* 44, 598-606
- Brant, J.W.A. & Nalbandov, A.V., 1956. Role of the sex hormones in albumen secretion by the oviduct of chickens. *Poult. Sci.* 35, 692-700
- Brown, C.R., Peinke, D. & Loveridge, A., 1996. Mortality in near-term ostrich embryos during artificial incubation. *Br. Poult. Sci.* 37, 73-85

- Brown, W.O. & Jackson, N., 1959. A study of the composition of the normal and hormone-stimulated oviduct of the common fowl, with special reference to its amino acid and nucleic acid content. *Poult. Sci.* 39, 602-611
- Bunter, K.L., Cloete, S.W.P., Van Schalkwyk, S.J. & Graser, H.-U., 2001. Factors affecting reproductive performance in farmed ostriches. *Proc. Assoc. Advmt. Anim. Breed. Genet.* 14, 43
- Button, C., Kabay, M. & Rawlin, G., 1996. Ostrich fading syndrome in Australia. In: Improving our understanding of ratites in a farming environment. *Proc. Rat. Conf. Manchester, UK. 23-26 March 1996.* Ed: Deeming, D.C., pp. 35-38
- Calder, P.C., 1999. Dietary fatty acids and the immune system. *Lipids.* 34, S137-S140
- Cho, P., Brown, R. & Anderson, M., 1983. Comparative gross anatomy of ratites. *Zoo Biol.* 3, 133-144
- Christians, J.K. & Williams, T.D., 1999. Organ mass dynamics in relation to yolk precursor production and egg formation in European starlings *Sturnus vulgaris*. *Physiol. Biochem. Zool.* 72, 455-461
- Cilliers, S.C., 1994. Evaluation of feedstuffs and the metabolisable energy and amino acid requirements for maintenance and growth in ostriches (*Struthio camelus*). PhD thesis. University of Stellenbosch, South Africa
- Cilliers, S.C., 1998. Feedstuff evaluation, metabolisable energy and amino acid requirements for maintenance and growth in ostriches. *Proc. 2nd Int. Rat. Cong. Oudtshoorn, South Africa.* 12-23
- Cilliers, S.C. & Angel, C.R., 1999. Basic concepts and recent advances in digestion and nutrition. In: *The Ostrich: Biology, Production & Health.* Ed. Deeming, D.C., CABI Publishing, Wallingford, England. pp. 105-128
- Cilliers, S.C., du Preez, J.J., Maritz, J.S. & Hayes, J.P., 1995. Growth curves of ostriches (*Struthio camelus*) from Oudtshoorn in South Africa. *Anim. Sci.* 61, 161-164
- Cilliers, S.C., Hayes, J.P., Maritz, J.S., Chwalibog, A. & Du Preez, J.J., 1994. True and apparent metabolisable energy values of lucerne and yellow maize in adult roosters and mature ostriches (*Struthio camelus*). *Anim. Production.* 59, 309-313
- Cilliers, S.C., Hayes, J.P., Chwalibog, A., Du Preez, J.J. & Sales, J., 1997. A comparative study between mature ostriches and adult cockerels with regard to the true and apparent digestibilities of amino acids. *Br. Poult. Sci.* 38, 311-313
- Cilliers, S.C., Hayes, J.P., Chwalibog, A., Du Preez, J.J. & Sales, J., 1998a. The additivity of the TME_n values of various ingredients in a complete diet for ostriches and adult roosters. *Anim. Feed Sci. Tech.* 71, 369-373
- Cilliers, S.C., Hayes, J.P., Chwalibog, A., Du Preez, J.J. & Sales, J., 1998b. A comparative study between roosters and mature ostriches with respect to true and apparent metabolisable energy of soybean oilcake and sunflower oilcake meal. *Anim. Sci.* In press
- Cilliers, S.C., Hayes, J.P., Chwalibog, A., Du Preez, J.J. & Sales, J., 1998c. Determination of energy, protein and amino acid requirements for maintenance and growth in ostriches. *Anim. Feed Sci. Tech.* 72, 283-292
- Cilliers, S.C., Hayes, J.P., Chwalibog, A., Du Preez, J.J. & Sales, J., 1999. Comparison of metabolisable energy values of different foodstuffs determined in ostriches and poultry. *Br. Poult. Sci.* 40, 491-494

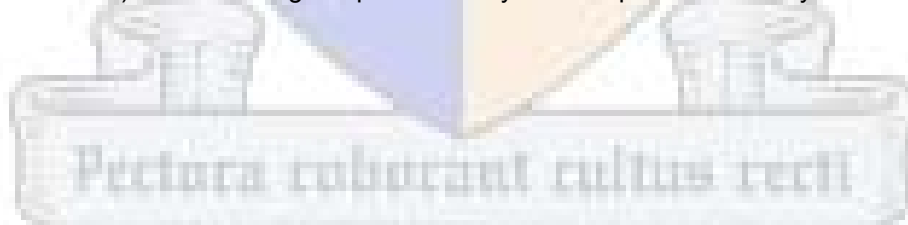
- Cilliers, S.C. & Van Schalkwyk, S.J., 1994. Volstruisproduksie (Ostrich production). Technical booklet. Little Karoo Agricultural Development Center, Oudtshoorn Experimental farm, P.O. Box 313, Oudtshoorn, 6620, South Africa
- Cloete, S.W.P., Lambrechts, H., Punt, K. & Brand, Z., 2001. Factors related to high levels of ostrich chick mortality from hatching to 90 days of age in an intensive rearing system. J. S. Afr. Vet. Assoc. 72, 197-202
- Coleman, A., 2008. Bright 2008 for Ostrich industry. Farmer's Weekly. 11 January. pp. 33
- Combs, G.F., 1968. Amino acid requirements of broilers & layers. Proc. Md Nutr. Conf. Fd Manfrs, pp. 86-96
- Dawson, A., Goldsmith, A.R., Nicholls, T.J. & Follett, B.K., 1986. Endocrine changes associated with the termination of photofractoriness by short daylengths and thyroidectomy in starlings (*Sturnus vulgaris*). J. Endocrinol. 110, 73-79
- Deeming, D.C., 1989a. Failure to turn eggs during incubation: development of the area vasculosa and embryonic development. J. Morphology. 201, 179-186
- Deeming, D.C., 1989b. Characteristics of unturned eggs: critical period, retarded embryonic growth and poor albumen utilization. Br. Poult. Sci. 30, 239-249
- Deeming, D.C., 1995. Factors affecting hatchability during commercial incubation of ostrich (*Struthio camelus*) eggs. Br. Poult. Sci. 36, 51-65
- Deeming, D.C., 1996a. Microbial spoilage of ostrich (*Struthio camelus*) eggs. Br. Poult. Sci. 37, 689-693
- Deeming, D.C., 1996b. Production, fertility and hatchability of ostrich (*Struthio camelus*) eggs on a farm in the United Kingdom. Anim. Sci. 63, 329-336
- Deeming, D.C., Sibly, R.M. & Magole, I.L., 1996. Estimation of weight and body condition of ostriches (*Struthio camelus*) from body measurements. Vet. Rec. 139, 210-213
- Duerden, J.E., 1912. Experiments with ostriches XX. The anatomy and physiology of the ostrich. C. The internal organs. S. Afr. Agric. J. April/May. 1-27
- Du Preez, J.J., 1991. Ostrich nutrition and management. In: Recent advances in animal nutrition in Australia. Ed. Farrell, D.J., University of New England, Armidale, Australia. pp. 278-291
- Du Preez, J.J., Jarvis, M.J.F., Capatos, D. & de Kock, J., 1992. A note on growth curves for the ostrich (*Struthio camelus*). Anim. Prod. 54, 150-152
- Dykstra, C.R., and Karasov, W.H., 1992. Changes in gut structure and function of house wrens (*Troglodytes aedon*) in response to increased energy demand. Physiol. Zool. 65, 422-442
- Emmans, G.C., 1989. The growth of turkeys. In: Recent advances in turkey science, Poultry Science Symposium No. 21. Butterworths, London. pp. 135-166
- Emmans, G.C. & Fisher, C. 1986. Problems in nutritional theory, Poultry Science Symposium No.19. In: Nutrient requirements of poultry and nutritional research. Ed. Fisher, C. & Boorman, K.N., Butterworths, London. pp. 9-39
- Ferguson, N.S., Gous, R.M. & Emmans, G.C., 1994. Preferred components for the construction of a new simulation model of growth, feed intake and nutrient requirements of growing pigs, S. Afr. J. Anim. Sci. 24, 10-17

- Finkler, M.S., van Orman, J.B. & Sotherland, P.R., 1998. Experimental manipulation of egg quality in chickens: influence of albumen and yolk on the size and body composition of near-term embryos in a precocial bird. *J Comp. Physiol. B.* 168, 17-24
- Foster, R.G., Plowman, G., Goldsmith, A.R. & Follett, B.K., 1987. Immunohistochemical demonstration of marked changes in the LHRH system of photosensitive and photorefractory European starlings (*Sturnus vulgaris*). *J. Endocrinol.* 115, 211-220
- Fowler, M.E., 1991. Comparative clinical anatomy of ratites. *J. Zoo & Wildlife Med.* 22, 204-227
- Freeman, B.M. & Vince, M.A., 1974. Development of the avian embryo. Chapman & Hall, London. pp. 119-159
- Gaunt, A.S., Hikida, R.S., Jehl, J.R. & Fenbert, L., 1990. Rapid atrophy and hypertrophy of an avian muscle. *Auk.* 107, 649-659
- Geluso, K. & Hayes, J.P., 1999. Effects of dietary quality on basal metabolic rate and internal morphology of European starlings (*Sturnus vulgaris*). *Physiol. Biochem. Zool.* 72, 189-197
- Glatz, P.C., Ru, Y.J., Hastings, M.Y., Black, D. & Rayner, B., 2003. On farm assessment of high fibre dietary sources for grower and finisher ostriches. *Int. J. Poult. Sci.* 2, 293-299
- Gonzalez, A., Satterlee, D.G., Moharer, F. & Cadd, G.G., 1999. Factors affecting ostrich egg hatchability. *Poult. Sci.* 78, 1257-1262
- Gous, R.M., 1993. The use of simulation models in estimating the nutritional requirements of broilers. Australian Poultry Science Symposium 5. University of Sydney, Sydney, Australia. 1-9
- Gous, R.M. & Brand, T.S., 2008. Developing simulation models for food intake and growth of ostriches, 4th Int. Rat. Sci. Sym, 1-4 July 2008, Brisbane, Australia
- Gous, R.M. & Morris, T.R., 1985. Evaluation of a diet dilution technique for measuring the response of broiler chickens to increasing concentrations of lysine. *Br. Poult. Sci.* 26, 147-161
- Griffin, H.D., Perry, M.M & Gilbert, A.B., 1984. Yolk formation. In: Physiology and Biochemistry of the domestic fowl. Ed. Freeman, B.M., Academic Press. London. 5, pp. 345-380
- Hertz, R. & Sebrell, W.H., 1944. Impairment of response to stilbestrol in the oviduct of chicks deficient in L. Casei Factor ("Folic acid"). *Sci.* 100, 293-294
- Hicks, K.D., 1993. Ostrich reproduction. In: Zoo and Wild Animal Medicine. Current Therapy 3. Ed. Fowler, M.E., W.B. Saunders, Philadelphia, pp. 203-206
- Huchzermeyer, F.W., 1996. High mortality in ostrich eggs and hatchlings due to egg-washing. *J. S.A. Vet. Assoc.* 67, 3
- Iji, P.A., van der Walt, J.G., Brand, T.S., Boomker, E.A. & Booyse, D., 2003. Development of the digestive tract in the ostrich (*Struthio camelus*). *Arch. Anim. Nutr.* 57, 217-228
- Irons, P., 1995. Ostrich reproductive research: quantum physics or back to the drawing board? Proc. 6th annual cong. Livestock Health and Production Group of the S.A. Vet. Assoc. June. Warmbaths. 140-148
- Jozefiak, D., Rutkowski, A. & Martin, S.A., 2004. Carbohydrate fermentation in the avian ceca: a review. *Anim. Feed Sci. Tech.* 113, 1-15

- King, J.R., 1972. Energetics of reproduction in birds. In: Breeding biology of birds; Proceedings of a symposium on breeding behaviour and reproductive physiology in birds. Ed: Farner, D.S., National Academy of Sciences, Washington, D.C. pp. 78-120
- Kritzinger, W.J., Brand, T.S., Hoffman, L.C. & Mellett, F.D., 2009. A description of body composition change in ostriches (*Struthio camelus*) under optimal feeding conditions. South Africa Society of Animal Science's 43rd Congress, 28-30 July 2009, Bergville, South Africa
- Kwakkel, R.P., Ducro, B.J. & Koops, W.J., 1993. Multiphasic analysis of growth of the body and its chemical components in White Leghorn pullets. *Poult. Sci.* 72, 1421-1432
- Lambrechts, H., 2004. Reproductive efficiency of ostriches (*Struthio camelus*). PhD Thesis, University of the Free State, South Africa
- MacAlister, A., 1864. On the anatomy of the ostrich (*Struthio camelus*). *Proc. Royal Irish Academy.* 9, 1-24
- Martin, P.A., Bradford, G.D. & Gous, R.M., 1994. A formal method of determining the dietary amino acid requirements of laying-type pullets during their growing period. *Br. Poult. Sci.* 35, 709-724
- McDonald, P., Edwards, R.A., Greenhalgh, J.F.D. & Morgan, C.A., 2002. *Animal Nutrition*. 6th edition. 284. Prentice Hall, Harlow, England. pp. 286
- Murakami, H., Akiba, Y. & Horiguchi, M., 1992. Growth and utilization of nutrients in newly-hatched chick with or without removal of residual yolk. *Growth development aging.* 56, 75-84
- Mushi, E.Z., Binta, M.G. & Chabo, R.G., 2004. Yolk sac utilization in ostrich (*Struthio camelus*) chicks. *Onderstepoort J. Vet. Res.* 71, 247-249
- Muwasi, R.T., Baranga, J., Kayanja, F.I.B & Schliemann, H., 1982. The oviduct of the ostrich *Struthio camelus massaicus*. *J. Orn.* 123, 425-433
- Naber, E.C., 1979. The effect of nutrition on the composition of eggs. *Poult. Sci.* 58, 518-528
- Nash, D.M., Hamilton, R.M.G. & Hulan, H.W., 1995. The effect of dietary herring meal on the omega-3 fatty acid content of plasma and egg yolk lipids of laying hens. *Can. J. Anim. Sci.* 75, 247-253
- Noble, R.C., Speake, B.K., McCartney, R., Foggin, C.M. & Deeming, D.C., 1996. Yolk lipids and their fatty acids in the wild and captive ostrich (*Struthio camelus*). *Comp. Biochem. Physiol.* 113B, 753-756
- Oka, T. & Schimke, R.T., 1969. Interaction of estrogen and progesterone in chick oviduct development. I. Effect of estrogen and progesterone on tubular gland cell function. *J. Cell Biol.* 43, 123-137
- O'Malley, B.W., McGuire, W.L., Kohler, P.O. & Korenman, S.G., 1969. Studies on the mechanisms of steroid hormone regulation of synthesis of specific proteins. *Rec. Prog. Horm. Res.* 25, 105-160
- Palmer, B.D. & Guilette Jr., L.J., 1991. Oviductal proteins and their influence on embryonic development in birds and reptiles. In: *Egg incubation: its effects on embryonic development in birds and reptiles*. Ed: Deeming, D.C. & Ferguson, M.W.J., Cambridge University Press. Cambridge, UK. pp. 29-46
- Palmiter, R.D. & Wrenn, J.T., 1971. Interaction of estrogen and progesterone in chick oviduct development. III. Tubular gland cell cytodifferentiation. *J. Cell Biol.* 50, 598-615
- Philbey, A.W., Button, C. Gestier, A.W., Munro, B.E., Glastonbury, J.R.W., Hindmarsh, M. & Love, S.C.J., 1991. Anasarca and myopathy in ostrich chicks. *Aus. Vet. J.* 68, 237-240

- Piersma, T., Gudmundson, G.A. & Lilliendahl, K., 1999. Rapid changes in the size of different functional organs and muscle groups during refueling in a long-distance migrating shorebird. *Physiol. Biochem. Zool.* 72, 405-415
- Richards, P.D.G., Richards, P.A. & Lee, M.E., 2000. Ultrastructural characteristics of ostrich eggshell: outer shell membrane and the calcified layers. *J. S. Afr. Vet. Ass.* 71, 97-102
- Richardson, K.C., 1935. The secretory phenomena in the oviduct of the fowl, including the process of shell formation examined by micro-incineration technique. *Phil. Trans. R. Soc. London (B)*. 225, 149-195
- Romanoff, A.A. & Romanoff, A.J., 1949. *The avian egg*. Wiley, New York, pp. 175-252
- Rose, M.E. & Orland, E., 1981. Immunoglobulins in the egg, embryo and young chick. *Devel. Comp. Immunol.* 5, 15-20
- Saino, N., Martinelli, R. & Moller, A.P., 2001. Immunoglobulin plasma concentration in relation to egg laying and male ornamentation of female barn swallows (*Hirundo rustica*). *J. Evol. Biol.* 14, 95-109
- Saino, N., Dall'ara, P., Martinelli, R. & Moller, A.P., 2002. Early maternal effects and antibacterial immune factors in the eggs, nestlings and adults of the barn swallow. *J. Evol. Biol.* 15, 735-743
- Samson, J., 1997. Prevalent diseases of ostrich chicks farmed in Canada. *Can. Vet. J.* 38, 425-428
- Scott, M.L., Nesheim, M.C. & Young, R.J., 1969. *Nutrition of the chicken*. M.L. Scott & Assoc., Ithaca, New York
- Smith, W.A., Cilliers, S.C., Mellet, F.D. & Van Schalkwyk, S.J., 1995a. Nutrient requirements and feedstuff values in ostrich production. *Feed Compounder*, September 1995, pp. 22-29
- Smith, W.A., Cilliers, S.C., Mellet, F.D. & Van Schalkwyk, S.J., 1995b. Ostrich Production – A South African Perspective. In: *Biotechnology in the Feed Industry: Proceedings of Alltech's Eleventh Annual Symposium*. Ed. Lyons, T.P. & Jacques, K.A., Nottingham University Press, Nottingham, England. pp. 175-197
- Soley, J.T. & Groenewald, H.B., 1999. Reproduction. In: *The Ostrich: Biology, Production & Health*. Ed. Deeming, D.C., CABI Publishing, Wallingford, England. pp. 129-157
- South African Ostrich Business Chamber, 2002. Oudtshoorn, South Africa
- Speake, B.K., Noble, R.C. & Murray, A.M.B., 1998. The utilization of yolk lipids by the chick embryo. *World's Poultry Sci. J.* 54, 319-334
- Sturkie, P.D., 1965. *Avian Physiology*. Comstock, New York. pp. 447-514
- Surai, P.F., Speake, B.K., Bortolotti, G.R. & Negro, J.J., 2001. Captivity diets alter egg yolk lipids of a bird of prey (the American Kestrel) and of a Galliforme (the Red-Legged Partridge). *Physiol. Biochem. Zool.* 74, 153-160
- Swart, D., 1988. Studies on the hatching, growth and energy metabolism of the ostrich chick (*Struthio camelus*). PhD thesis. University of Stellenbosch, South Africa
- Swart, D., Siebrits, F.K. & Hayes, J.P., 1993. Utilization of metabolizable energy by ostrich (*Struthio camelus*) chicks at two different concentrations of dietary energy and crude fibre originating from lucerne. *S. Afr. J. Anim. Sci.* 23, 136-141
- Terzich, M. & Vanhooser, S., 1993. Postmortem findings of ostriches submitted to the Oklahoma Animal Disease Diagnostic Laboratory. *Avian Diseases*. 37, 1136-1141

- Tullett, S.G. & Deeming, D.C., 1987. Failure to turn eggs during incubation: effects on embryo weight, development of the chorioallantois and absorption of albumen. *Br. Poult. Sci.* 28, 239-250
- Verwoerd, D.J., Deeming, D.C., Angel, C.R. & Perelman, B., 1999. Rearing environment around the world. In: *The ostrich – Biology, production and health*. Ed: Deeming, D.C., CABI Publishing, CAB International, Wallingford, pp. 191-216
- Vezina, F. & Williams, T.D., 2003. Plasticity in body composition in breeding birds: What drives the metabolic costs of egg production? *Physiol. Biochem. Zool.* 76, 716-730
- Walzem, R.L., 1996. Lipoproteins and the laying hen: form follows function. *Poult. Avian Biol. Rev.* 7, 31-64
- Wang, Y.W., Cherian, G., Sunwoo, H.H. & Sim, J.S., 2000a. Dietary polyunsaturated fatty acids significantly affect laying hen lymphocyte proliferation and immunoglobulin G concentration in serum and egg yolk. *Can. J. Anim. Sci.* 80, 597-604
- Wang, Y.W., Field, C.J. & Sim, J.S., 2000b. Dietary polyunsaturated fatty acids alter lymphocyte subset proportion and proliferation, serum immunoglobulin G concentration, and immune tissue development in chicks. *Poult. Sci.* 79, 1741-1748
- Wang, Y.W., Ajuyah, A.O., Sunwood, H.H., Cherians, G. & Sim, J.S., 2002. Maternal dietary n-3 fatty acids alter the spleen fatty acid composition and bovine serum albumin-induced wing web swelling in broilers. *Poult. Sci.* 81, 1722-1727
- Wellock, I.J., Emmans, G.C. & Kyriazakis, I., 2004. Describing and predicting potential growth in the pig. *Anim. S78*, 379-388
- Williams, T.D., 1994. Intraspecific variation in egg size and egg composition in birds: effects on offspring fitness. *Biol. Rev.* 68, 35-59
- Williams, T.D., 2005. Mechanisms underlying the costs of egg production. *Biosci.* 55.1, 39-48
- Williams, T.D. & Ames, C.A., 2004. Top-down regression of the avian oviduct during late oviposition in a small passerine bird. *J. Experimental Biol.* 207, 263-268
- Winsor, C.P., 1932. The Gompertz curve as a growth curve. *Proc. National Academy Sci.* 18, 1-8
- Yu, J.Y.-L. & Marquart, R.R., 1973. Synergism of testosterone and estradiol in the development and function of the magnum from the immature chicken (*Gallus domesticus*) oviduct. *Endocrinology.* 92, 563-572
- Yu, J.Y.-L. & Marquardt, R.R., 1974. Hyperplasia and hypertrophy of the chicken (*Gallus Domesticus*) oviduct during a reproductive cycle. *Poult. Sci.* 53, 1096-1105
- Yu, J.Y.-L., Marquart, R.R. & Kondra, P.A., 1972. Development, cellular growth and function of the avian oviduct. III. Electrophoretic and immunological patterns of soluble proteins from each region of domestic fowl (*Gallus domesticus*) oviduct during a reproductive cycle. *Comp. Biochem. Physiol.* 42B, 627-635



Chapter 2

The effect of dietary protein and amino acid levels on the production of breeding ostriches

Abstract

A study was conducted with breeding ostriches to determine the influence of dietary protein and amino acid levels on production. Five rations, each with a different protein concentration and accompanying amino acid profile, were provided to both females and males over two subsequent breeding seasons at a level of 2.5 kg feed/bird/day. The respective diets contained 7.5%, 9.1%, 10.8%, 12.3% and 14.0% protein with a constant ME value of 9.2 MJ ME/kg feed. A tendency ($P=0.08$) for higher total egg production (overall mean \pm SE, 39.1 \pm 3.6 eggs/female/season) was observed with amongst dietary protein level. No differences between diets were found for the number of unfertilized eggs (9.1 \pm 1.8), dead-in-shell chicks (8.2 \pm 1.3), the number of chicks hatched (19.5 \pm 2.5) and change in the mass of females (-16.2 \pm 1.6kg). The 12.3% protein diet resulted in the lowest change in mass for males ($P<0.05$). Significant difference ($P<0.05$) for egg weight was observed for the 7.5%, 9.1% and 14.0% CP diet, which also decreased linearly ($P<0.05$) as the dietary protein content increased. It was concluded that the production of ostrich breeding pairs were independent of a fairly wide range of dietary protein inclusion levels of this study.

Keywords: ostriches, nutrition, protein, lysine, egg production, chick production, mass change

Introduction

The protein and amino acid requirements of breeding ostriches is not well-defined. Values from poultry have been used in the past, but today we know that this is not recommended, because it may results in an overestimation of the requirements of ostriches (Cilliers, 1994). Du Preez (1991) calculated the protein and amino acid requirements for egg production according to the weight of the egg and the mass of the female bird. According to du Preez (1991), the nutrient requirements for egg production can be estimated by using information like egg mass, frequency of egg laying, and the composition of the egg. A study by Brand *et al.* (2003) revealed that dietary protein level, ranging from 10.5%–16.5% crude protein, had no effect on the egg production of breeding female ostriches. Brand *et al.* (2005) on the other hand reported that dietary protein and amino acid level, ranging from 8.5%–14% crude protein, had no effect on production data. The influence of dietary protein and specifically methionine level on the production of laying poultry has been previously reported (Harms *et al.*, 1998).

Production studies need to be performed to determine the requirements of the essential nutrients for ostriches and it is therefore imperative that the amino acid requirements of breeding ostriches are drafted in order to

determine the quantity of amino acids needed for production. Quantification of nutrient requirements can help overcome some of the challenges in the industry, which will ensure the financial well-being of ostrich producers.

The aim for this study is to determine the effect of dietary protein and amino acids on the production characteristics of breeding ostriches.

Material and Methods

One hundred female breeding ostriches were divided into five groups, consisting of twenty birds per group. Each bird was assigned to one of five different diets, provided at 2.5 kg /bird/day over two subsequent breeding seasons. The dietary crude protein levels were 7.5%, 9.1%, 10.8%, 12.3% and 14.0%. Energy levels were held constant at 9.2 MJ ME/kg feed. Breeding pairs were kept in a 1:1 ratio in a single breeding camp and rations were given to both males and females. The ages of the birds varied between 2 and 8 years. The diets were given in the 2004/2005 and 2005/2006 seasons. The annual breeding season in South Africa starts in June and ends in January the following year. The studies were conducted in Oudtshoorn, South Africa. Table 2.1 list the raw materials and formulated nutrient composition of each diet.

Records were kept of total egg and chick production, dead-in-shell, and infertile egg production. The live mass of the birds were measured at the onset and end of the season to calculate the change in mass over the season. Statistical analysis was performed on the data, using Statgraphics (2005) for two-way analysis of variance. The main effects in the analysis of variance (ANOVA) were the dietary protein and the year of season. To analyze the effect of age on the data, an ANACOVA was done using Statistica (2009). Diet was used as categorical predictor and age as the covariate.

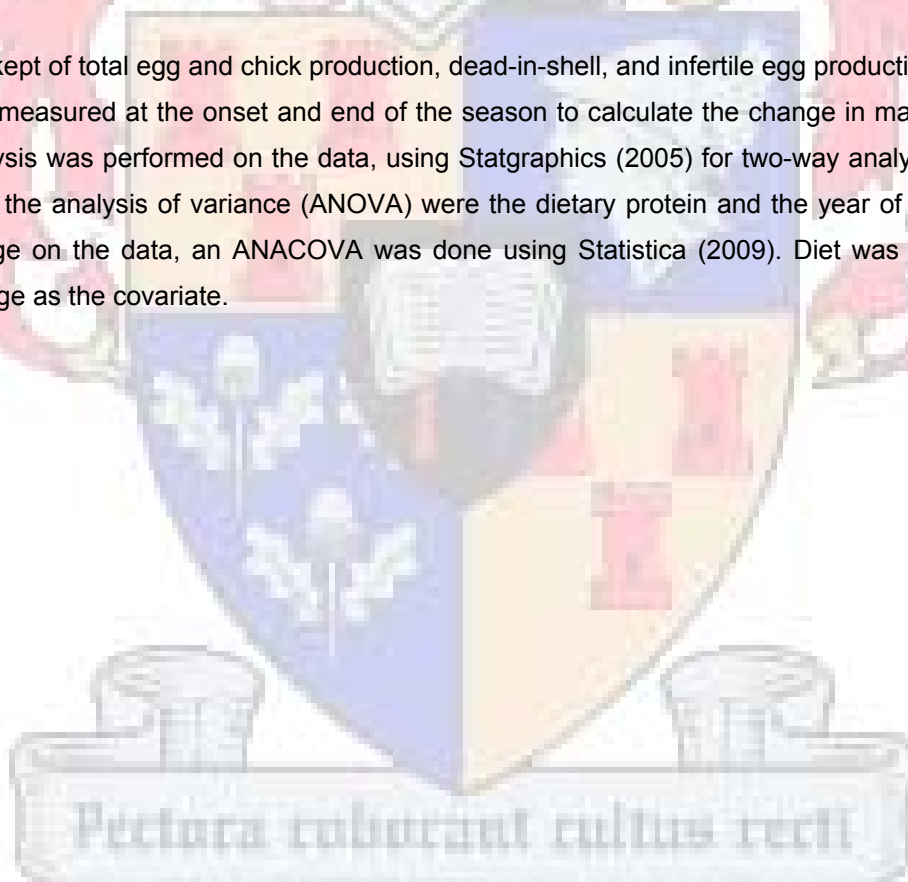


Table 2.1 Ingredient and nutrient composition of the five experimental diets with increasing crude protein content provided to ostrich birds during two seasons

Ingredients (kg/ton feed)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Oat Bran	490	467	444	420	397
Maize	207	195	184	172	160
Wheat Bran	197	148	99	49	0
Lucerne hay	0	38	75	113	150
Soyabean oilcake meal	0	27	53	80	106
Sunflower oilcake meal	0	23	45	68	90
Limestone	60	58	56	54	52
Molasses	25	25	25	25	25
Monocalciumphosphate	12	12	12	12	12
Salt	4.00	4.00	4.00	4.00	4.00
Vitamin & Mineral Premix	2.50	2.50	2.50	2.50	2.50
Synthetic Lysine	1.66	1.25	0.83	0.42	0.00
Synthetic Threonine	0.78	0.00	0.70	0.67	0.63
Synthetic Methionine	0.48	0.46	0.43	0.41	0.38
Nutrients					
Metabolisable energy (MJ ME/kg feed)	9.20	9.20	9.20	9.20	9.20
Crude protein (%)	7.50	9.10	10.8	12.3	14.0
Lysine (%)	0.29	0.36	0.44	0.51	0.58
Threonine (%)	0.23	0.29	0.34	0.40	0.45
Methionine+Cysteine (%)	0.21	0.27	0.32	0.38	0.43

Results and Discussion

Figure 1 shows the total monthly egg production for the seasons. Table 2.2 provides the production records of the breeding birds for the two consecutive breeding seasons.

The ANOVA table indicates a significant difference between the seasons for egg production ($P < 0.05$). The egg production of breeding ostriches is highly variable. Bunter *et al.* (2001) reported variable reproductive performance in breeding ostriches. The season of the year also causes variation in egg production of broiler breeders (Chaney & Fuller, 1975). Other factors causing variation in egg production are differences in body size (Chambers *et al.*, 1974; Pearson & Herron, 1980) and level of feed intake (Blair *et al.*, 1976; McDaniel *et al.*, 1981; Wilson & Harms, 1986).



Table 2.2 The effect of different protein and lysine levels on performance of female breeding ostriches

Crude protein (%)	7.5	9.1	10.8	12.3	14.0	
Lysine levels (%)	0.29	0.36	0.44	0.51	0.58	se²
Egg production (eggs/female/season) (n ¹ =100)	36.8 ^a	47.3 ^a	43.5 ^a	36.5 ^a	35.6 ^a	3.6
Unfertilized eggs (eggs/female/season)	8.2 ^a	11.8 ^a	7.9 ^a	7.3 ^a	10.4 ^a	1.8
Dead-in-shell chicks (chicks/female/season)	7.5 ^a	10.4 ^a	8.6 ^a	8.5 ^a	6.2 ^a	1.3
Chick production (chicks/female/season)	18.3 ^a	22.5 ^a	23.3 ^a	17.4 ^a	15.9 ^a	2.5
Males' starting mass (kg)	126.7 ^a	125.0 ^a	122.9 ^a	119.8 ^a	125.1 ^a	2.8
Males' end mass (kg)	115.1 ^a	115.3 ^a	111.0 ^a	116.0 ^a	113.5 ^a	2.3
Females' starting mass (kg)	117.7 ^a	117.9 ^a	116.8 ^a	117.2 ^a	118.8 ^a	1.9
Females' end mass (kg)	103.8 ^a	103.1 ^a	99.0 ^a	102.6 ^a	100.1 ^a	1.7
Males' mass change (kg)	-13.4 ^a	-10.2 ^a	-11.7 ^a	-3.6 ^b	-11.6 ^a	2.0
Females' mass change (kg)	-15.2 ^a	-14.4 ^a	-17.8 ^a	-14.8 ^a	-18.8 ^a	1.6
Egg weight (g)	1403.9 ^a	1409.8 ^a	1366.4 ^{ab}	1367.7 ^{ab}	1315.5 ^b	17.5

^{a,b} means in rows with different superscripts denotes significant differences (P<0.05)

¹ n=number of females

² se=standard error

A tendency (P=0.08) amongst the different diets was observed in total egg production (eggs/female/season). Crude protein levels between 9-11% tend to maximize egg production, as found in this study. The minimum protein requirement must be determined in order to prevent reduced production. Lopez & Leeson (1995) found no effect of dietary protein on egg production for broiler breeders. Spratt & Leeson (1987) indicated that 19 g protein/day is sufficient to maintain normal reproductive performance through peak egg production for broiler breeders. No significant effect was observed by Pearson & Herron (1981) on reproductive performance (egg production) when dietary protein intake varied from 19.5 – 27 g/bird/d. Joseph *et al.* (2000) suggested that higher dietary protein levels are diverted directly into egg formation, thereby enhancing egg production in broiler breeders.



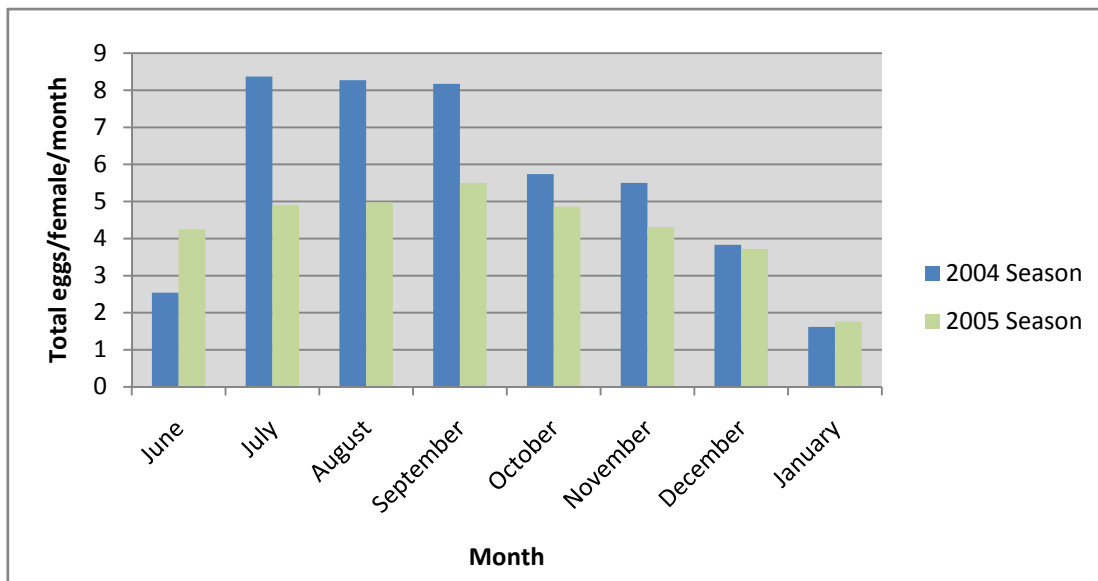


Figure 1 Total number of eggs produced per female per year for two consecutive years

No significant difference ($P > 0.05$) amongst the diets was observed for total number of unfertilized eggs produced, although there was a significant difference between the seasons ($P < 0.05$). Obese females tend to lay infertile eggs (Smith *et al.*, 1995). Weight control therefore plays an important part as a management tool or strategy to increase egg production and decrease infertile eggs. Incompatibility between a breeding pair and infertility of males also plays a role (Smith *et al.*, 1995).

The total amount of dead-in-shell eggs produced did not differ significantly ($P > 0.05$) amongst the dietary treatments. A difference ($P < 0.05$) was observed between the seasons for dead-in-shell eggs.

Not any of the females produced significantly more chicks nor did the two seasons differ from each other ($P > 0.05$) amongst the dietary treatments. Data for chick production was transformed in order to prevent violations of the assumption for analysis of variance, which stated that the variances amongst the response groups are equal.

Mass change of the birds denotes the difference in mass between the mass of the bird at the onset of the season and at the end of the season. The 12.3% diet resulted in the lowest change in mass ($P < 0.05$) for the males during the season (-3.6 ± 2.0 kg).

Pectora roburant cultus recti

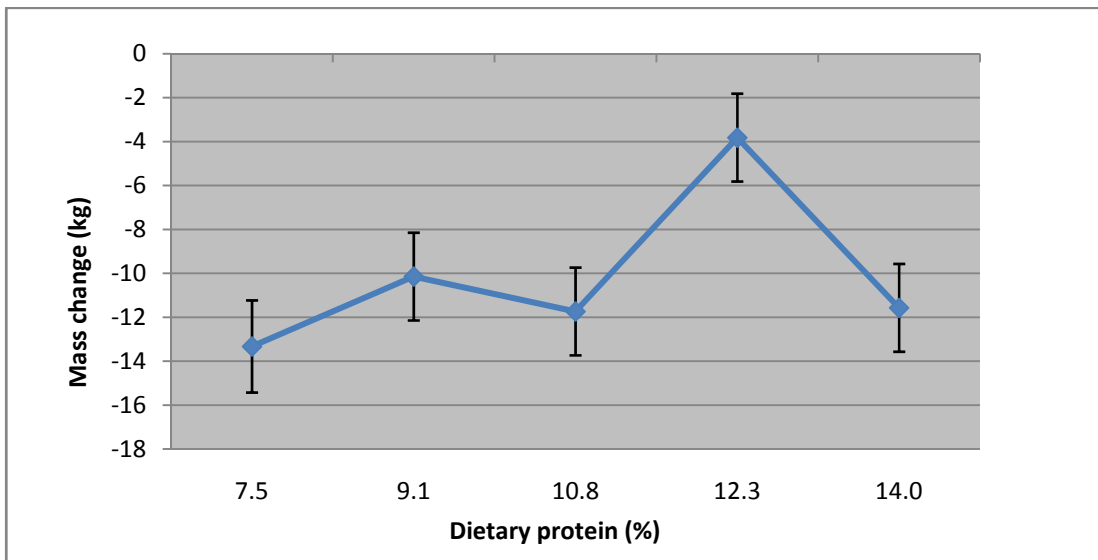


Figure 2 Average change in mass (kg) of male birds receiving diets varying in crude protein levels

None any of the diets resulted in significant differences in change of mass ($P > 0.05$) of the female birds (-16.2 ± 1.6 kg). All females lost mass on all five experimental diets, which indicated that body reserves were used for reproduction. Broiler breeders that were fed 10% crude protein were lighter than birds fed 16% crude protein in research performed by Lopez & Leeson (1995).

The various treatments exerted a statistically significant effect ($P < 0.05$) on the weight of the eggs produced. A difference was noted between the 7.5% (1403.9 ± 18.5 g) and 14% protein diet (1315.1 ± 16.1 g), and 9.1% (1409.8 ± 17.0 g) and 14% protein diet. A significant linear regression was noted ($y = -13.7x + 1520.6$; $SE_{est} = 38.1$; $P < 0.05$; $R^2 = 0.08$), with a correlation of -0.28 . It remains unclear why the increased dietary protein resulted in lighter eggs being laid. One reason might be that the increased dietary protein tended to be used for other body functions and not for egg formation, thereby resulting in an increased requirement of energy to convert protein into energy. A study by Brand *et al.* (2003) revealed that dietary protein levels between 10.5% - 16.5% had no effect on egg weight. The observed variation could be ascribed to genetics. The influence of genetics on egg weight of chickens has been reported (Jaap, 1971; Richard & Cochez, 1971; Chambers *et al.*, 1974). Increased dietary methionine (Carey *et al.*, 1991; Shafer *et al.*, 1996; Shafer *et al.*, 1998) and lysine (Prochaska *et al.*, 1996; Novak *et al.*, 2004) levels results in increased egg weight in studies conducted with poultry.



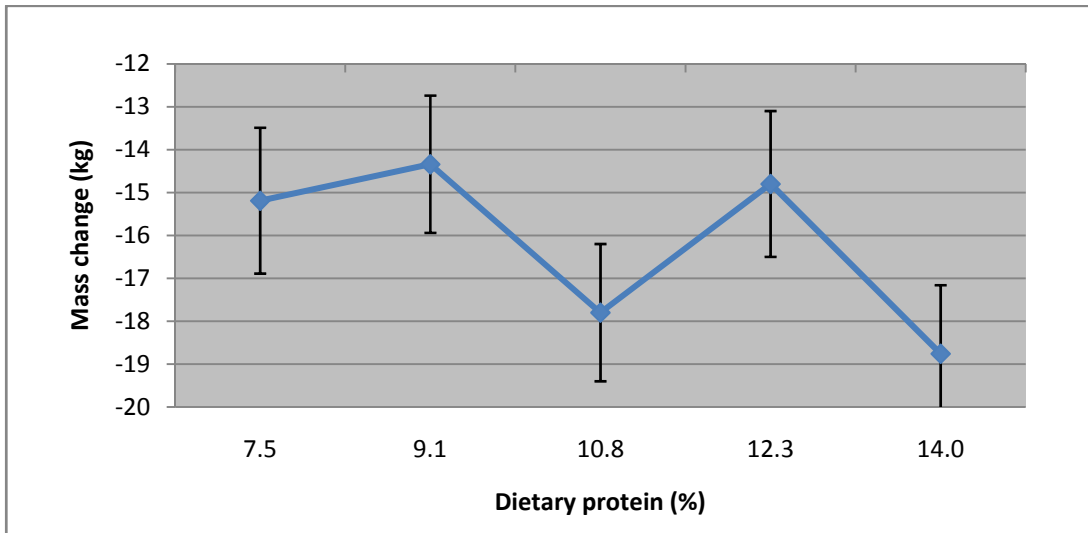


Figure 3 Average change in mass (kg) of female birds receiving diets varying in crude protein levels

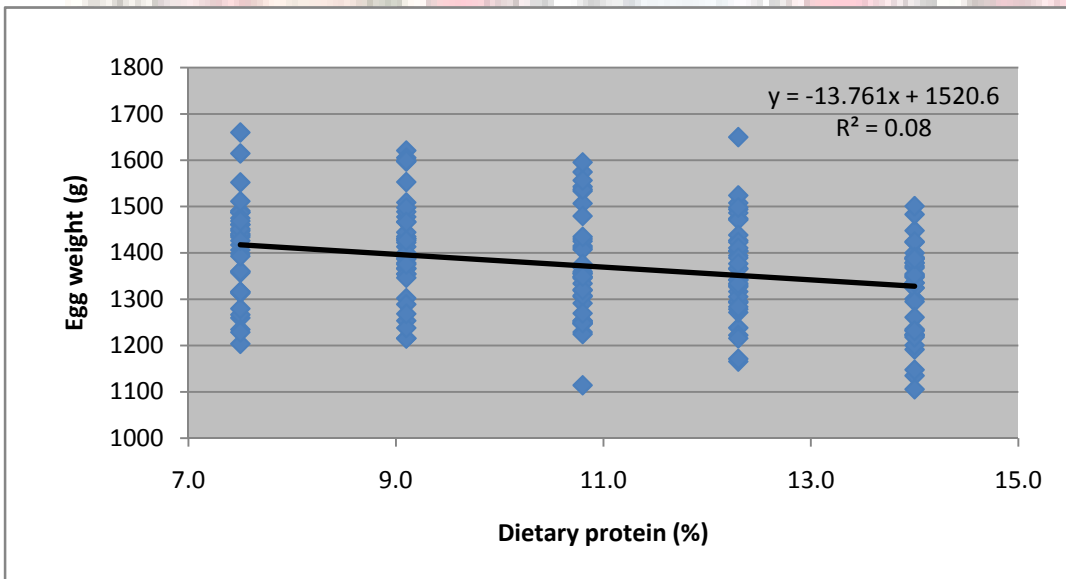


Figure 4 Average egg weight (g) of ostrich female birds receiving diets varying in crude protein levels

The age of the female (years) contributed to the data, significantly affecting ($P < 0.05$) egg and chick production, infertile and dead-in-shell eggs, change in mass of females. Results of analysis of covariance, when age of the bird were held as the covariate, stated that older birds tend to lay more eggs, together with an increase in chicks, infertile and dead-in-shell eggs. Old female birds lost the least mass during the season. Kritzinger *et al.* (2009) reported that the maximum weight at maturity under assumed optimal conditions of an ostrich (119.4kg) will be

achieved at 943 days or 2.5 years of age. It can be assumed that any excess feed after mature weight will be turned into body fat (Pond *et al.*, 2005), which may explain why older birds lost the least mass. Figures 5-9 shows the production and change in mass of females at different age groups.

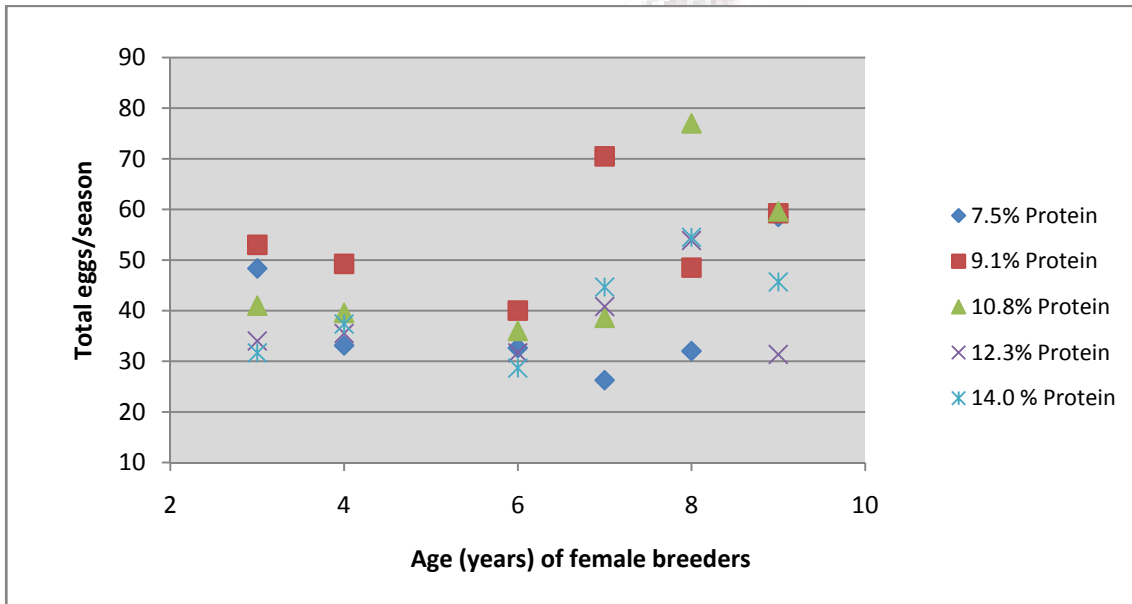


Figure 5 Effect of age of female birds (years) on average total egg production



Figure 6 Effect of age of female birds (years) on average number of chicks hatched

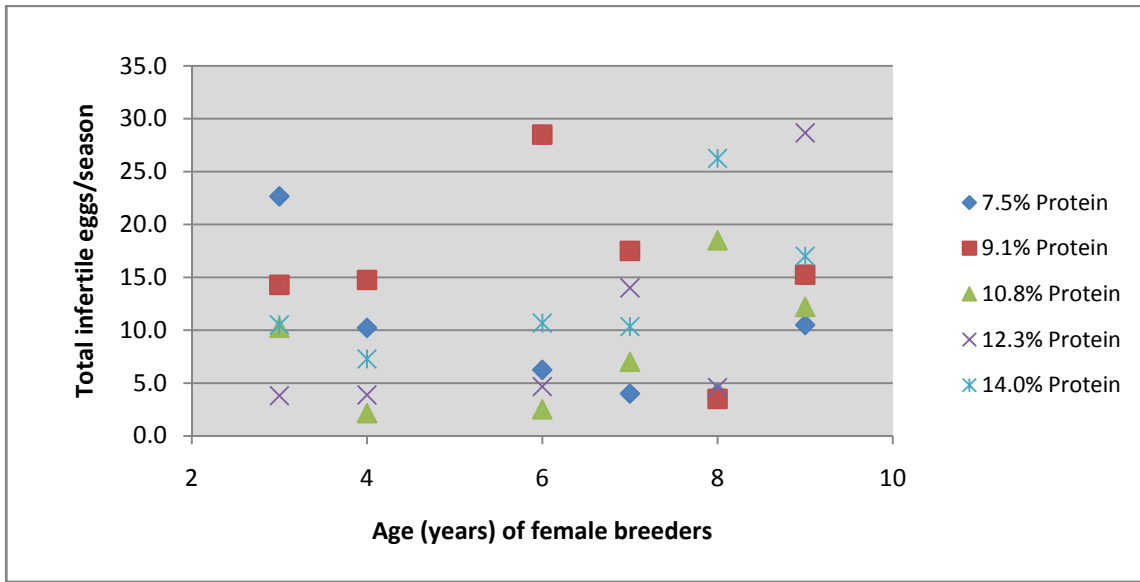


Figure 7 Effect of age of female birds (years) on average total infertile egg production

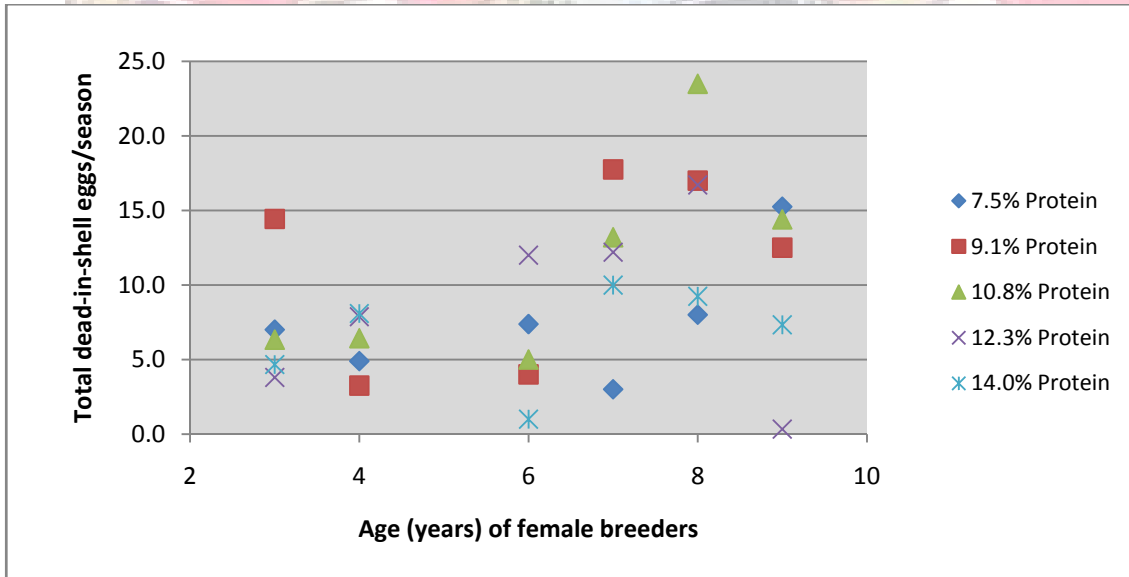


Figure 8 Effect of age of female birds (years) on average total dead-in-shell egg production





Figure 9 Effect of age (years) on average change in mass of female birds

Conclusion

Dietary protein and amino acid levels as used in this study had no significant effect on the production characteristics of breeding ostriches. Only a tendency for higher total egg production was noted. Seasonal effects influenced the variation of total egg production, since ANOVA revealed a difference between the year of season for total egg production. It is also important to focus on the female's need for amino acids and not on the need for crude protein, since the efficiency of protein utilization depends largely on the amino acid composition of the ration (Lopez & Leeson, 1995). Future research should focus on the requirements of essential amino acids for optimum production levels. The effect of different levels of protein on production, fed during the pre-lay period, can also provide useful guidelines for the nutrient requirements of female breeding ostriches. Broiler breeders are fed through feed restriction and in breeding ostriches it is feasible to feed the birds *ad libitum*, although this may not be the most economical option.

References

Blair, R.R., McCowan, M.M. & Bolton, W., 1976. Effect of food regulation during the growing and laying stage on the productivity of broiler breeders. *Br. Poult. Sci.* 17, 215-223

- Brand, T.S., Brand, Z. & Engelbrecht, S., 2005. The effect of dietary energy and protein (amino acid) on the performance of breeder ostriches. Proc. 3rd Int. Rat. Sci. Sym. 14-16 October 2005, Madrid, Spain
- Brand, Z., Brand, T.S. & Brown, C.R., 2003. The effect of dietary energy and protein levels on production in breeding female ostriches. Br. Poult. Sci. 44, 598-606
- Bunter, K.L., Cloete, S.W.P., Van Schalkwyk, S.J. & Graser, H.-U., 2001. Factors Affecting Reproductive Performance in Farmed Ostriches. Proc. Assoc. Advmt. Anim. Breed. Genet. 14, 43
- Carey, J.B., Asher, R.K., Angel, J.F. & Lowder, L.S., 1991. The influence of methionine on egg composition. Poult. Sci. 70. Suppl. 1, Abstract, 151
- Chambers, J.R. Smith, A.D., McMillan, I. & Friars, G.W., 1974. Comparison of normal and dwarf broiler breeders hens. Poult. Sci. 53, 864-870
- Chaney, L.W. & Fuller, H.L., 1975. The relation of obesity to egg production in broiler breeders. Poult. Sci. 54, 200-208
- Cilliers, S.C., 1994. Evaluation of feedstuffs and the metabolizable energy and amino acid requirements for maintenance and growth of ostriches (*Struthio camelus*). PhD thesis. University of Stellenbosch, South Africa
- Du Preez, J.J., 1991. Ostrich nutrition and management. In: Recent advances in animal nutrition in Australia. Ed. Farrell, D.J., University of New England, Armidale, Australia. pp. 278-291
- Harms, R.H., Russell, G.B., Harlow, H. & Ivey, F.J., 1998. The influence of methionine on commercial laying hens. J. Appl. Poult. Res. 7, 45-52
- Jaap, R.G., 1971. Effect of sex-linked genes on body size and reproduction. World's Poult. Sci. J. 27, 281-282
- Joseph, N.S., Robinson, F.E., Korver, D.R. & Renema, R.A., 2000. Effect of dietary protein intake during the pullet-to-breeder transition period on early egg weight and production in broiler breeders. Poult. Sci. 79, 1790-1796
- Kritzinger, W.J., Brand, T.S., Hoffman, L.C. & Mellett, F.D., 2009. A description of body composition change in ostriches (*Struthio camelus*) under optimal feeding conditions. South Africa Society of Animal Science's 43rd Congress, 28-30 July 2009, Bergville, South Africa
- Lopez, G. & Leeson, S., 1995. Response of broiler breeders to low-protein diets. 1. Adult breeder performance. Poult. Sci. 74, 685-695
- McDaniel, G.R., Brake, J. & Eckman, M.K., 1981. Factors affecting broiler breeder performance. 4. The inter-relationship of some reproductive traits. Poult. Sci. 60. 1792-1797
- Novak, C., Yakout, H. & Scheideler, S., 2004. The combined effects of dietary lysine and total sulfur amino acid level on egg production parameters and egg components in Dekalb Delta laying hens. Poult. Sci. 83, 977-984
- Pearson, R.A. & Herron, K.M., 1981. Effects of energy and protein allowances during lay on the reproductive performance of broiler breeder hens. Br. Poult. Sci. 22, 227-239
- Pond, W.G., Church, D.C., Pond, K.R. & Schoknecht, P.A., 2005. Basic animal nutrition and feeding. 5th edition. John Wiley & Sons, Inc., pp.100

- Prochaska, J.F., Carey, J.B. & Shafer, D.J., 1996. The effect of L-Lysine intake on egg component yield and composition in laying hens. *Poult. Sci.* 75, 1268-1277
- Richard, F.H. & Cochez, L.P., 1971. Effects of the sex-linked dwarf gene, *dw*, on performance of hens in a meat-type strain of domestic fowl. *World's Poult. Sci. J.* 27, 292
- Shafer, D.J., Carey, J.B. & Prochaska, J.F., 1996. Effects of dietary methionine intake on egg component yield and composition. *Poult. Sci.* 75, 1080-1085
- Shafer, D.J., Carey, J.B., Prochaska, J.F. & Sams, A.R., 1998. Dietary methionine intake effects on egg component yield, composition, functionality, and texture profile analysis. *Poult. Sci.* 77, 1056-1062
- Smith, W.A., Cilliers, S.C., Mellet, F.D. & Van Schalkwyk, S.J., 1995. Ostrich Production – A South African Perspective. In: *Biotechnology in the Feed Industry: Proceedings of Alltech's Eleventh Annual Symposium*. Ed. Lyons, T.P. & Jacques, K.A., Nottingham University Press, Nottingham, England. pp. 175-197
- Spratt, R.S. & Leeson, S., 1987. Broiler breeder performance in response to diet protein and energy. *Poult. Sci.* 66, 683-693
- Wilson, H.R. & Harms, R.H., 1986. Performance of broiler breeders as affected by body weight during the breeding season. *Poult. Sci.* 65, 1052-1057



Chapter 3

Genotype x dietary protein level interaction of breeding ostriches

Abstract

A study was conducted with breeding ostriches to determine if the dietary protein/amino acid levels interacts with the breeding value for chick and egg production of female breeding ostriches. The effect of dietary protein was compared within a breeder flock, which consisted of females with a high potential for egg production compared to females with a low potential. Five rations, each with a different protein concentration, were provided to both females and males over one breeding season at a level of 2.5 kg/bird/day. The respective diets included 7.5%, 9.1%, 10.8%, 12.3% and 14.0% crude protein. No significant interaction ($P>0.05$) occurred between genotype and the dietary protein concentration for both egg and chick production. The high-potential ostriches produced more total eggs than their low-potential contemporaries (49.9 ± 4.7 vs. 30 ± 4.8 ; $P<0.01$) as expected. Dietary protein accordingly did not affect total egg production (40.0 ± 4.7). The high potential ostriches similarly produced more chicks (25.1 ± 3.3 vs. 13.8 ± 3.3 ; $P<0.01$) as expected. Chick production was independent of dietary CP concentration (19.5 ± 3.3 ; $P>0.05$). No difference was observed amongst the high potential (-17.1 ± 3.0 kg) and low potential (16.4 ± 3.4 kg) birds for mass change (kg). It was concluded that the reproduction of ostrich females, with a high potential and low potential for egg and chick production, were fairly independent of dietary protein concentrations as supplied in the current study.

Keywords: ostriches, nutrition, lysine, egg production, chick production, high breeding value, low breeding value

Introduction

Various poultry breeds exist, each with its unique characteristics and striving to reach its genetic potential (Emmans, 1981). Sterling *et al.* (2006) reported that researchers are aware of the different production levels offered by gender, genotype, and genotype crosses; and how nutrition can influence those production levels. In addition, Sterling *et al.* (2006) noted that the nutrient requirements of different chicken genotypes are not similar and recommended that nutritional requirements need future revision as genotypes undergo selection and change. It is not clear whether dietary protein interacts with the genotype of the bird for broiler breeders and for ostrich breeding birds. Sterling *et al.* (2006) noticed a three-way interaction in broilers between dietary protein and lysine levels, and genotype, when observed for body weight gain, feed intake and feed conversion rate. Genotype-nutrition interactions have been reviewed by Decuypere *et al.* (2007). Possible interactions need to be elucidated, in order to make dietary formulations more accurate.

The focus of the following investigation was to scrutinize whether five different dietary protein levels might interact with two different genotypes.

Material and Methods

One hundred female breeding ostriches were divided into five groups, consisting of twenty birds per group. Females were allocated according to their estimated breeding value. In each group, ten females had a high potential for egg production and ten females had a low potential for egg production (Cloete *et al.*, 2008). Each bird was assigned to one of five different diets, provided at 2.5 kg feed/bird/day. The dietary crude protein levels were 7.5%, 9.1%, 10.8%, 12.3% and 14.0%. Energy levels were held constant at 9.2 MJ ME/kg feed. Breeding pairs were kept in a 1:1 ratio in a single breeding camp and rations given to both males and females. The ages of the birds varied between 2 and 8 year. Table 3.1 list the raw materials and formulated nutrient composition of each diet. The research was undertaken in Oudshoorn (South Africa) during the 2005/2006 season. The annual breeding season in South Africa starts in June and ends in January the following year. Records were kept of total egg and chick production. The live mass of the birds were measured at the onset and end of the season to calculate the change in mass over the season.

Statistical analysis was performed on the data, using Statgraphics (2005). The main effects in the two-way analysis of variance were the dietary protein and the breeding value of the birds.

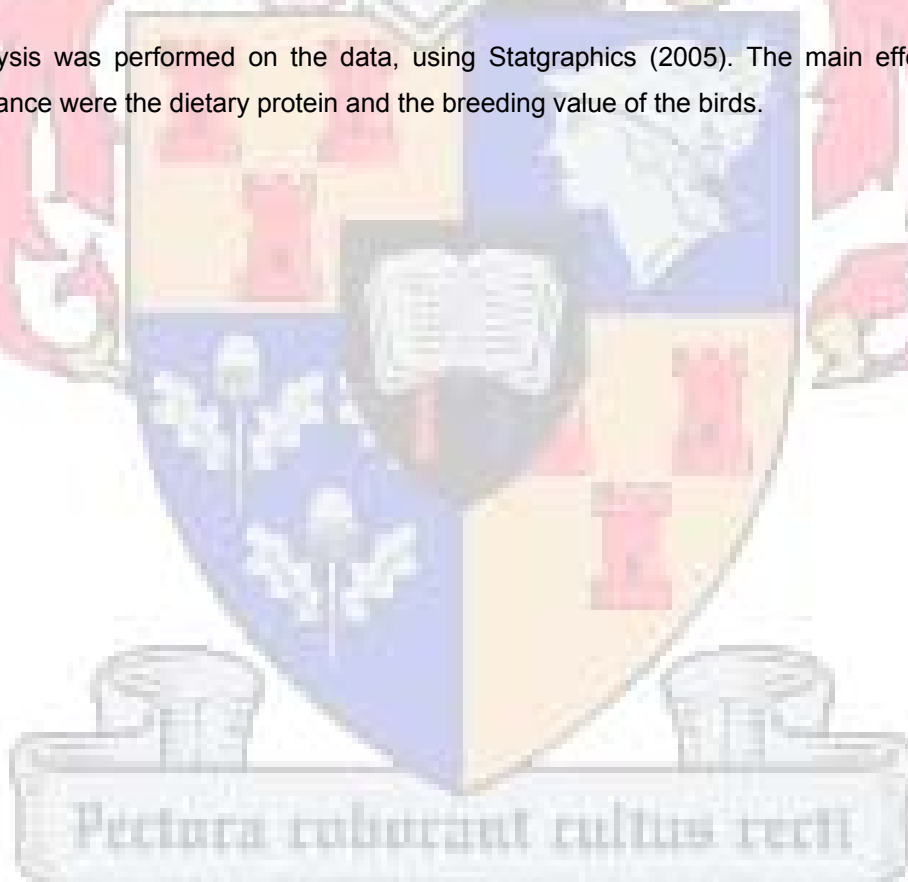


Table 3.1 Ingredient and nutrient content of the five experimental diets with increasing crude protein content provided to ostrich birds during one season

Ingredients (kg/ton feed)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Oat Bran	490	467	444	420	397
Maize	207	195	184	172	160
Wheat Bran	197	148	99	49.25	0
Lucerne	0	38	75	113	150
Soyabean oilcake meal	0	27	53	80	106
Sunflower oilcake meal	0	23	45	68	90
Limestone	60	58	56	54	52
Molasses	25	25	25	25	25
Monocalciumphosphate	12	12	12	12	12
Salt	4.00	4.00	4.00	4.00	4.00
Vitamin&Mineral Premix	2.50	2.50	2.50	2.50	2.50
Synthetic Lysine	1.66	1.25	0.83	0.42	0.00
Synthetic Threonine	0.78	0.00	0.70	0.67	0.63
Synthetic Methionine	0.48	0.46	0.43	0.41	0.38
Nutrients					
Metabolisable energy (MJ ME/kg feed)	9.20	9.20	9.20	9.20	9.20
Crude protein (%)	7.50	9.10	10.80	12.30	14.00
Lysine (%)	0.29	0.36	0.44	0.51	0.58
Threonine (%)	0.23	0.29	0.34	0.40	0.45
Methionine+Cysteine (%)	0.21	0.27	0.32	0.38	0.43

Results and Discussion

Table 3.2 reports the mean egg production for both high and low potential ostriches.

Table 3.2 Mean and standard error for egg production (total eggs/female) of ostrich females with a high and low potential for egg production given diets with increasing crude protein content during one season

Dietary protein (%)	Low potential	High potential
7.5	29.1 ^a	47.3 ^b
9.1	34.6 ^a	58.1 ^b
10.8	29.5 ^a	55.6 ^b
12.3	26.1 ^a	47.2 ^b
14.0	30.7 ^a	41.5 ^b
Standard error	4.7	4.8

^{a,b}: means in rows with different superscripts differ significantly ($P < 0.05$)

No significant interaction for egg production between dietary protein and genotype could be observed ($P > 0.05$). Total egg production was not affected by dietary protein level ($P > 0.05$).

Table 3.3 reports the mean chick production for both high and low potential ostriches.

Table 3.3 Mean and standard error for number of chicks hatched (total chicks hatched/female) of ostrich birds with a high and low potential for egg production given diets with increasing crude protein content during one season

Dietary protein (%)	Low potential	High potential
7.5	11.7 ^a	25.7 ^b
9.1	12.8 ^a	30.5 ^b
10.8	15.9 ^a	30.5 ^b
12.3	15.0 ^a	20.2 ^b
14.0	13.8 ^a	18.5 ^b
Standard error	3.3	3.3

^{a,b}: means in rows with different superscripts differ significantly ($P < 0.05$)

No significant interaction for chick production between dietary protein and genotype could be observed ($P > 0.05$). Chick production was fairly constant ($P > 0.05$) irrespective of the different dietary protein treatments.

The change in mass (kg) of female birds with a high potential and low potential for egg production was investigated. Analysis of variance (ANOVA) revealed no significant difference amongst female birds with a high potential and low potential for egg production. Mean and standard error for the low potential and high potential females were respectively -16.4 ± 1.5 kg and -17.1 ± 1.4 kg. The nutrient partitioning to products or tissue, especially in the low potential females is unclear. Figure 1 shows the change in mass of the low and high potential birds at every dietary treatment.



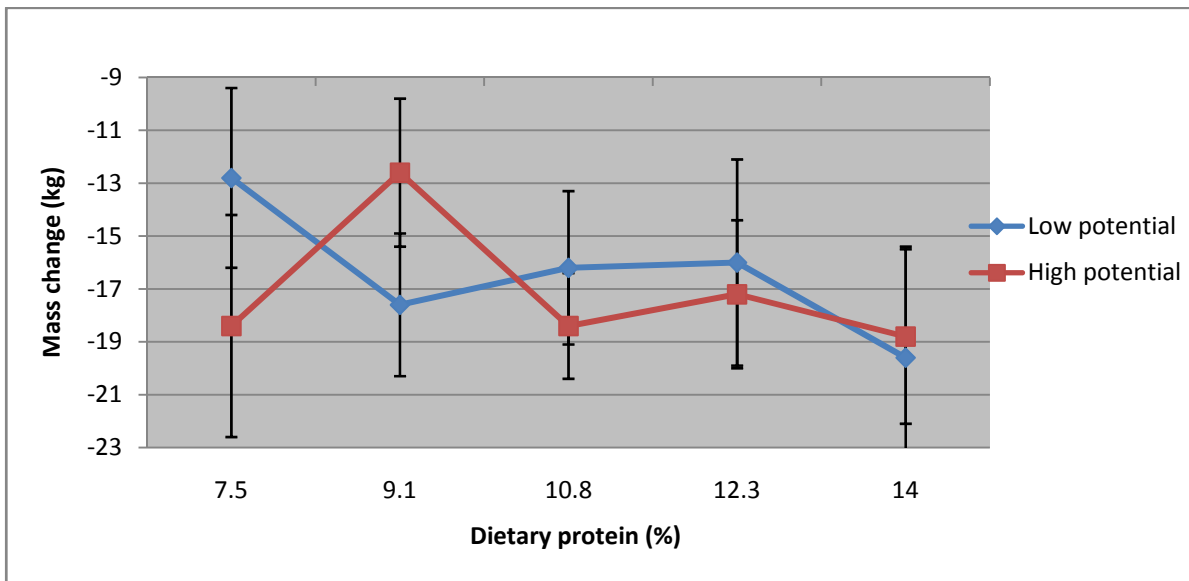


Figure 1 Average change in mass (kg) of high and low potential breeding female ostriches receiving diets varying in crude protein levels over the breeding season

Conclusion

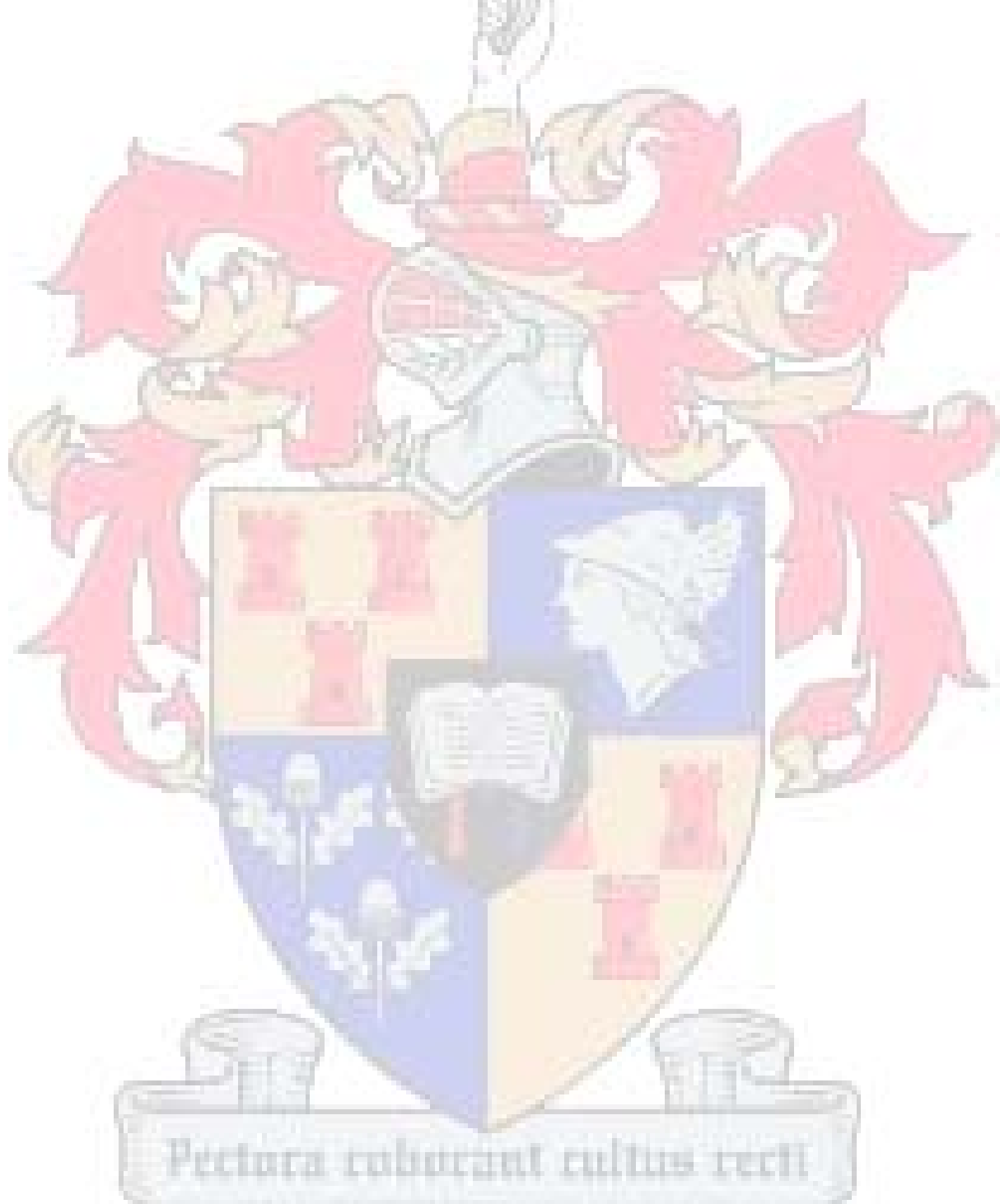
No statistical interaction ($P > 0.05$) were observed between dietary protein and genotype for total egg and chick production. It is evident that no unfavorable interactions or correlations exist in breeding ostriches (Cloete, 2006), as seen in the current study. Female ostriches that have a high or low potential for egg and chick production are therefore independent of a dietary crude protein range of 7.5 – 14.0 %. These results indicated that the higher production level due to breeding had not yet been reached where higher nutrient concentrations is in demand. This may also indicated that mean and low producers may be overfed in terms of crude protein and amino acid requirements, compared to the high producing genotypes.

References

- Cloete, S.W.P., 2006. Volstruushandleiding, Western Cape Department of Agriculture, Elsenburg, pp. 56-72
- Cloete, S.W.P., Brand, Z., Bunter, K.L. & Malecki, I.A., 2008. Direct responses in breeding values to selection of ostriches for liveweight and reproduction. *Aus. J. Exp. Agric.* 48, 1314-1319
- Decuyper, E., Onagbesan, O., Swennen, Q., Buyse, J. & Bruggeman, V., 2007. The endocrine and metabolic interface of genotype-nutrition interactions in broilers and broiler breeders. *World's Poult. Sci.* 63, 115-128

Emmans, G.C., 1981. A model of the growth and feed intake of *ad libitum* fed animals, particular poultry. In: Computers in animal production. Ed: Hillyer, G.M., Whittemore, C.T. & Gunn, R.G., British Society of Animal production occasional publication no. 5. BSAP, Edinburgh, Scotland. pp. 103-110

Sterling, K.G., Pesti, G.M. & Bakalli, R.I., 2006. Performance of different broiler genotypes fed diets with varying levels of dietary crude protein and lysine. *Poult. Sci.* 85, 1045-1054



Chapter 4

The effect of dietary energy level on the production and egg composition of breeding ostriches

Abstract

Six diets varying in ME content (7.5, 8.0, 8.5, 9.0, 9.5 and 10.0 MJ ME/kg) were provided to both males and females at an average rate of 3.4kg feed/bird/day. Dietary protein and lysine levels were held constant at 12% and 0.58% respectively. No differences ($P>0.05$) were observed for total eggs produced per female per season (44.3 ± 7.6), number of chicks hatched (15.6 ± 4.1), number of infertile eggs (11.8 ± 3.9) and for number of dead-in-shell eggs (11.9 ± 3.1). Analysis of variance revealed no significant difference in the change in mass of female birds ($P>0.05$). Differences ($P<0.05$) in the change in mass of male birds were observed, which ranged between 6.3 ± 2.7 kg and 18.4 ± 2.8 kg. Two eggs per diet per month were analyzed for crude protein, crude fat, and trace elements; and one egg per month for fatty acids. Eggs from the first and last month of the season were subjected to amino acid analysis. Analysis of variance showed no difference in the crude protein and fat ($P>0.05$) content between the experimental diets, as well as for the calcium content of eggshells. The eggs differed ($P<0.05$) in C18:3n-3 (linolenic acid) content as a result of the different treatments. For the number of the egg in the laying cycle, crude protein, C18:3n-3 and the fat content of eggs changed ($P<0.05$). In summary, the production of breeding female ostriches was not influenced by dietary energy at these feed intake levels and the energy supply for both male and female birds was in excess of their requirements, since both sexes increased in live mass during the season. Dietary treatment as used in this study revealed no differences in the composition of eggs in terms of protein and lipids. Overall the treatments had no influence on the reproductive efficiency of female ostriches.

Keywords: ostriches, nutrition, energy level, egg production, chick production, mass change, egg composition

Introduction

Reliable nutritional data for ostriches are scarce. A lack of nutritional data may contribute to a large variation in production of birds (Brand & Gous, 2006) as well as poor egg production records in breeding ostriches (Brand *et al.*, 2003). Practical diet specification for ostriches in various stages of production has been reported by Cilliers & Van Schalkwyk (1994). Swart *et al.* (1993) calculated the energy requirement for maintenance as 0.44 MJ/metabolic weight $\text{kg}^{0.75}/\text{day}$, and the efficiency of ME utilization for growth (ME_g) as 0.32 . Cilliers *et al.* (1998) on the other hand calculated 0.425 MJ/ (empty body weight) $\text{kg}^{0.75}/\text{day}$ as the energy requirement for maintenance of 7 month old ostriches and the efficiency of TME_n utilization for energy retention as 0.443 . ME utilization in ostriches is quite low in comparison with fowls and pigs. McDonald *et al.* (2002) for example reported a value of 0.9 and 0.85 respectively for fowls and pigs consuming balanced diets. Du Preez (1991) also

estimated the energy requirements of ostriches in 0.25 hectare breeding pens. The estimation includes the total MJ ME needed for egg production, maintenance, and activity; and is based on the mass of the body and the egg laid. According to du Preez (1991) for a 110kg female to lay a 1.4kg egg every second day during the 8 month breeding season 23 MJ ME/day is needed.

Brand *et al.* (2003) performed a study spanning two breeding seasons, to determine the effect of energy and protein provision on the production of female breeding ostriches. The females laid fewer eggs at longer intervals at the lower dietary energy level (7.5 MJ ME/kg feed at an intake of 2.5 kg feed per bird per day), but at higher dietary energy levels (8.5 and 9.5 MJ ME/kg feed at an intake of 2.5kg feed per bird per day) significant effects were recorded. Females also tend to loose more weight with diets containing less energy. It was concluded in this study that energy is the main constraint on egg production at crude protein and lysine levels exceeding 13.5% and 0.65% respectively; and a dietary energy level of 8.5 MJ ME/kg were sufficient for female breeding birds in these studies when consuming 2.5 kg feed per day. Nutrition related carry-over effects, from one season to the following season were also reported by Brand *et al.* (2002); and that a diet containing less than 8.5 MJ ME/kg may have an adverse effect on egg production in the following breeding season.

The experiment reported here was designed to determine the response to different dietary energy levels at higher feed intake levels (3.4kg/bird/day) at constant dietary protein and lysine levels; and to determine their influence on the chemical composition of eggs.

Material and Methods

Ninety pairs of breeding ostriches were divided into six groups, consisting of 15 breeding pairs per group. Six diets varying in ME content (7.5, 8.0, 8.5, 9.0, 9.5 and 10.0 MJ ME/kg feed) were provided at a rate of 3.4kg /bird/day to both males and females. Each pair was assigned to one of the six treatments for the duration of the trial. Breeding pairs were kept at a 1:1 ratio in single breeding camps. The age of the birds varied between 2 and 12 years. The study was undertaken in Oudtshoorn (South Africa) during the 2007/2008 breeding season. The annual breeding season in South Africa starts in June and ends in January the following year. Table 4.1 lists the ingredient and formulated nutrient composition of each diet and Table 4.2 the analyzed nutrient composition.



Table 4.1 Ingredient and nutrient content of the experimental diets varying in ME content fed to breeding ostriches

Composition (kg/ton feed)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Energy level (MJ ME/kg feed)	7.5	8.0	8.5	9.0	9.5	10.0
Oat Bran	670	536	402	268	134	0
Maize meal	0	110	220	330	440	550
Lucern hay	48.6	90.1	131.6	173	214.5	256
Soyabean oilcake	165	142.4	119.8	97.2	74.6	52
Flaxseed	0	10	20	30	40	50
Limestone	50	48.8	47.6	46.4	45.2	44
Dicalciumphosphate	30	26.9	23.9	20.8	17.8	14.7
Molasses	20	20	20	20	20	20
Salt	10	10	10	10	10	10
Mineral&Vitamin premix	2.50	2.50	2.50	2.50	2.50	2.50
Synthetic lysine	0.80	0.80	0.70	0.70	0.60	0.60
Synthetic methionine	1.90	1.60	1.20	0.90	0.50	0.20
Synthetic threonine	1.20	1.00	0.70	0.50	0.20	0.00
Nutrients						
ME (MJ ME/kg feed)	7.5	8.0	8.5	9.0	9.5	10.0
Crude protein (%)	12.0	12.0	12.0	12.0	12.0	12.0
Lysine (%)	0.58	0.58	0.58	0.58	0.58	0.58
Methionine-cysteine (%)	0.42	0.42	0.43	0.43	0.43	0.44
Threonine (%)	0.45	0.46	0.46	0.47	0.48	0.49
Arginine (%)	0.59	0.60	0.62	0.63	0.65	0.66
Tryptophane (%)	0.13	0.15	0.16	0.17	0.19	0.20
Isoleucine (%)	0.44	0.45	0.45	0.46	0.47	0.47
Fat (%)	1.10	1.90	2.70	3.50	4.20	5.00
Fatty acid C18:2 (%)	0.08	0.34	0.60	0.87	1.13	1.39
Fatty acid C18:3 (%)	0.02	0.21	0.41	0.61	0.80	1.00
Fiber (%)	20.7	18.4	16.1	13.8	11.4	9.10
Calcium (%)	2.70	2.70	2.60	2.60	2.50	2.40
Phosphorus (%)	0.60	0.60	0.60	0.60	0.50	0.50

Records were kept of total egg and chick production, dead-in-shell, and infertile egg production. The live mass of the birds were measured at the onset and end of the season to calculate the change in mass over the season. Feed was analyzed according to the Weende system (Van Soest, 1967). The True Metabilsable energy (TME) content of the feed was determined for poultry by using roosters in the feeding trial. The test feed was mixed with a basal diet (maize) in a 50:50 ratio. The roosters were adapted to the test feed and faeces were collected twice daily over a three day period. A model proposed by Brand & Gous (2006) was used to estimate the TME content of the test feed for ostriches.

Two eggs per month were kept from each diet for chemical analysis. Each egg was kept in a cool room after collection. Eggs were weighed and broken to separate the albumen, yolk and egg shell, each component was

weighted separately. The albumen and yolk were mixed after weighting and blended with a handheld blender. A representative sample was freeze-dried for chemical analysis. The chemical analysis for the mixture included: crude protein, amino acids, crude fat, fatty acids, and trace elements: and for the eggshell: calcium, phosphorus, and trace elements. Crude fat analysis was done on a Tecator Soxtec System HT 1043 extraction unit according to the method of Horwitz (2002). Fatty acid analysis was done on a Thermo Finnigan gas chromatogram, according to the method of Tichelaar *et al.* (1998); and the extraction method is described by Folch *et al.* (1957). Crude protein was conducted on a Leco FP-528 model, according to the method explained by Horwitz (2002). Eleven eggs in the first month and twelve eggs in the last month were subjected to amino acid analysis. Amino acid content was determined by LCMS analysis using a Waters API Quattro Micro Instrument. The method by Phenomenex (2003) was used. Trace element analysis is explained by ALASA (1998) and was performed on a Thermo ICP Spectrometer.

Statistical analysis was performed on the data, using Statgraphics (2005) for one-way ANOVA. To analyze the effect of the number of the egg in the laying cycle and age on the data, an ANACOVA was done using Statistica (2009). Diet was used as the categorical predictor, and the number of the egg in the laying cycle and age as the covariate. The number of the egg in the laying cycle was also divided into six categories. The first category represents the first 15 egg, the second category the second 15 eggs, the third category the third 15 eggs, the fourth category the fourth 15 eggs, the fifth category the fifth 15 eggs and the sixth category the last 15 eggs of the laying cycle.

Table 4.2 Analyzed nutrient composition of the six experimental diets varying in ME content fed to breeding ostriches

Nutrient composition	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
TME (MJ ME/kg feed)	8.06	5.25	8.20	7.27	8.13	9.13
Crude protein (%)	13.3	12.6	11.6	11.1	11.4	10.9
Dry Material (%)	92.0	92.1	91.5	91.0	90.7	90.6
Ash (%)	13.3	11.3	10.4	11.2	10.1	10.3
Fat (%)	2.10	2.50	3.20	3.90	4.30	4.90
Crude fiber (%)	20.6	18.3	16.3	15.5	13.3	8.90
Calcium (%)	3.00	3.00	3.20	3.10	2.80	2.60
Phosphorus (%)	0.50	0.70	0.70	0.60	0.50	0.50

Results and Discussion

Production results for breeding ostriches fed diets with an increasing ME content are provided in Table 4.3.

Table 4.3 Production results of breeding ostriches fed experimental diets varying in ME content

Energy level (MJ ME/kg feed)	7.5	8.0	8.5	9.0	9.5	10.0	
Crude protein (%)	12.0	12.0	12.0	12.0	12.0	12.0	
Lysine levels (%)	0.58	0.58	0.58	0.58	0.58	0.58	se ²
Egg production (eggs/female/season) (n ¹ =90)	40.7 ^a	35.3 ^a	50.4 ^a	42.6 ^a	49.9 ^a	47.1 ^a	7.6
Chick production (chicks/female/season)	17.5 ^a	11.4 ^a	12.3 ^a	16.5 ^a	20.8 ^a	15.1 ^a	4.1
Dead-in-shell eggs (eggs/female/season)	9.10 ^a	11.7 ^a	12.9 ^a	11.5 ^a	14.1 ^a	11.9 ^a	3.1
Infertile eggs (eggs/female/season)	9.10 ^a	8.30 ^a	19.4 ^a	10.7 ^a	9.40 ^a	13.9 ^a	3.9
Males' start mass (kg)	112.5 ^a	113.1 ^a	119.3 ^a	111.9 ^a	114.9 ^a	113.6 ^a	3.2
Males' end mass (kg)	119.6 ^a	124.7 ^a	126.3 ^a	126.8 ^a	126.1 ^a	131.5 ^a	3.6
Females' start mass (kg)	109.9 ^a	112.3 ^a	110.0 ^a	106.8 ^a	113.6 ^a	109.1 ^a	3.3
Females' end mass (kg)	114.8 ^a	119.5 ^a	117.5 ^a	117.6 ^a	128.1 ^a	126.0 ^a	4.2
Mass change of males (kg)	7.10 ^{ab}	11.6 ^{ab}	6.30 ^a	14.6 ^{ab}	12.0 ^{ab}	18.4 ^b	2.8
Mass change of females (kg)	4.90 ^a	7.20 ^a	9.30 ^a	11.5 ^a	14.8 ^a	16.4 ^a	3.5
Egg weight (g)	1421.9 ^a	1450.5 ^a	1361.4 ^a	1373.7 ^a	1407.3 ^a	1326.7 ^a	34.6

^{a,b} means in rows with different superscripts differ significantly (P<0.05)

¹n=number of females

²se=standard error

No differences were observed ($P>0.05$) for total eggs produced per female per season (44.3 ± 7.6), number of chicks hatched (15.6 ± 4.1), number of infertile eggs (11.8 ± 3.9), or number of dead-in-shell eggs (11.9 ± 3.1) due to a change in the dietary energy value. The age of the female contributed to the data, affecting ($P<0.05$) egg and chick production, and tended ($P=0.05$) to affect the change in mass of females. ANACOVA, when age was held as the covariate, stated that older birds tend to lay more eggs, together with an increase in chick production. Old female birds tend to gain more body mass on dietary energy treatments, more nutrients are possibly stored as body reserves as the bird ages. Kritzinger *et al.* (2009) reported that the maximum weight at maturity under assumed optimal conditions of an ostrich (119.4kg) will be achieved at 943 days or 2.5 years of age and can be assumed that any excess feed after mature weight will be turned into body fat (Pond *et al.*, 2005). Data for the change in mass of females may have been skewed due to the two year old females.

The average change in mass of female birds was 10.7 ± 3.5 kg. ANOVA analysis revealed no significant difference in the change in mass of female birds on different treatments ($P>0.05$), although regression analysis revealed an increase of 2.4 kg per bird per 0.5 MJ increase in dietary energy value ($y = 2.4x + 2.45$; $SE_{est} = 13.19$; $R^2 = 0.09$; $P<0.05$). Due to the fact that the females increased in mass on each treatment, it may be assumed that the energy provided exceeded the requirements of the birds. It is assumed in this study that any excess dietary energy is turned into body fat, which leads to an increase in body weight. Lin *et al.* (1980) stated in studies with broilers that when caloric intake is more than the body's requirement for energy, the excess food is stored as fat in broilers. Pond *et al.* (2005) explained that energy intake which is more than the current needs results in a net deposition of triglycerides and the animal will consequently become fatter. For growing pigs it was noticed that protein that was not deposited as protein was shifted to a pool of energy, that was utilized for adenosine triphosphate synthesis or lipid deposition (van Milgen *et al.*, 2001). An increase in live weight during the last three months indicates that not all the ingested energy is used for egg production (Lambrechts, 2006).



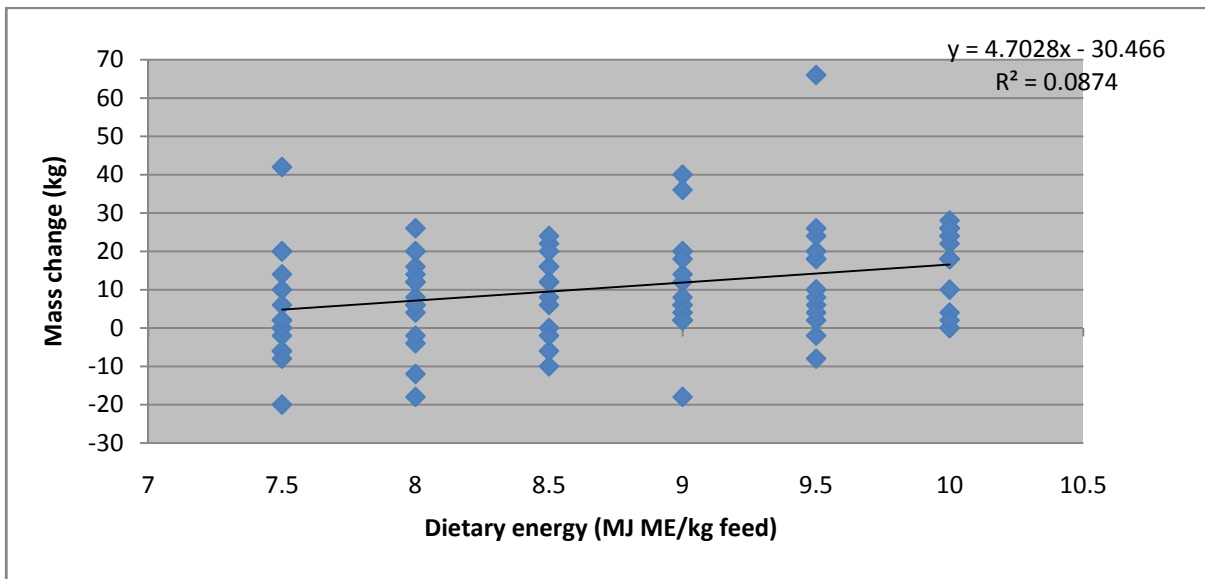


Figure 1 Change in mass of female ostrich birds receiving diets with increasing ME content

Significant differences ($P < 0.05$) in the change in mass of male birds were observed, ranging between 6.3 ± 2.7 kg and 18.4 ± 2.8 kg. The significant difference was between the 8.5 and 10.0 MJ ME/kg diet. A linear regression line was fitted on the data ($y = 1.89x + 5$; $SE_{est} = 10.5$; $R^2 = 0.09$; $P < 0.05$), indicating a growth of 1.9 kg per 0.5 MJ increase in dietary energy value for the trial period. The differences between the males can be ascribed to the higher fat accretion in the bodies of those males that were fed a diet higher in ME content. Due to weight gain, the energy provided also exceeded their requirements (Pond *et al.*, 2005).



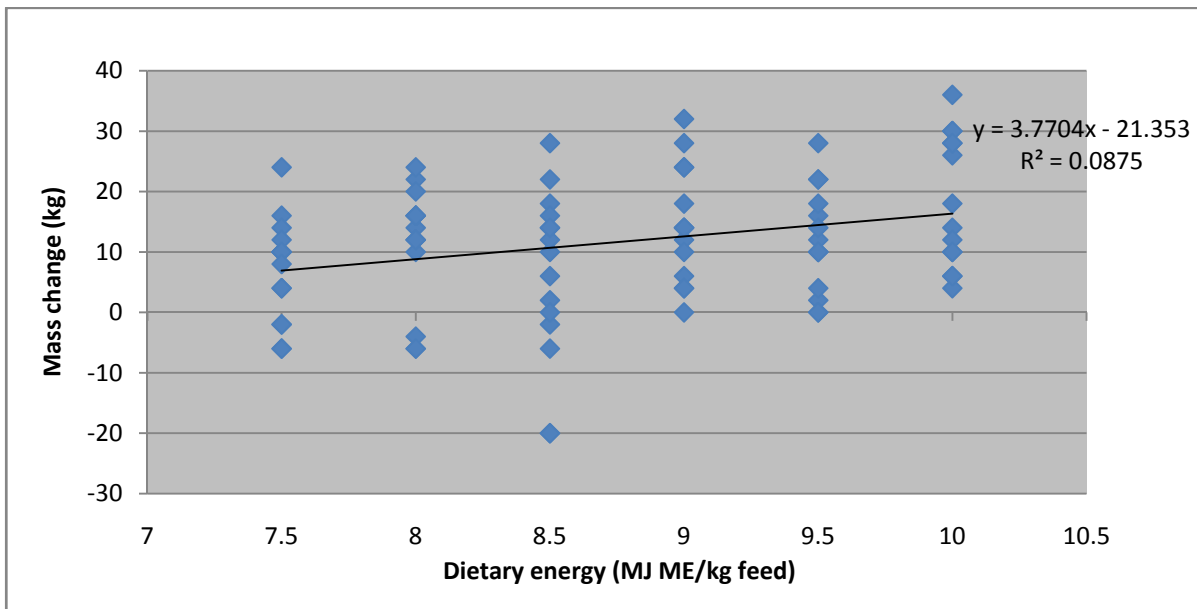


Figure 2 Change in mass of male birds receiving diets with increasing ME content



Figure 3 Effect of age of female birds (years) on average total egg production



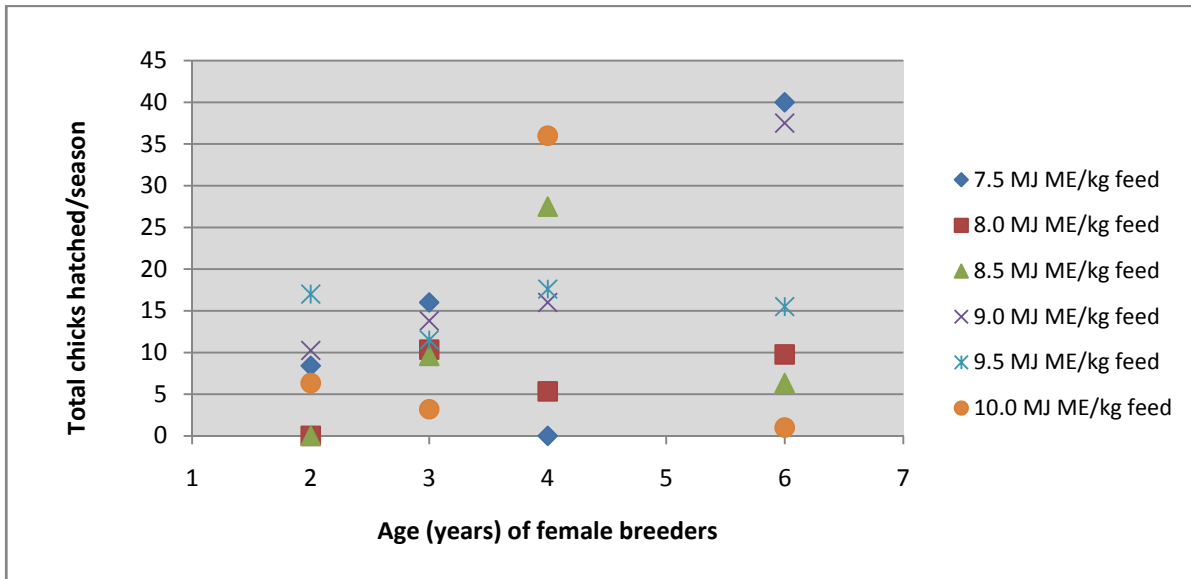


Figure 4 Effect of age of female birds (years) on average total chick production



Figure 5 Effect of age (years) on average change in mass of females

Table 4.4 reports the physical characteristics of ostrich eggs. The treatments in this study had no statistically significant effect ($P > 0.05$) on the weight of the eggs (Mean weight of 1390 ± 34.5 g). A linear regression applied to the data ($y = -33.6x + 1684.1$; $SE_{est} = 128.5$; $P < 0.05$; $R^2 = 0.05$) revealed that only 5% of the difference in egg

weight could be ascribed to dietary treatment. Whitehead *et al.* (1993) reported for laying hens that dietary fats are more effective in influencing egg weight due to their influence on yolk and albumen weight. It was also reported that egg weight is enhanced by fatty acids of medium chain length and moderate degree of unsaturation. It is of interest to note that egg weight might be influenced by oviduct mass of the female bird, since Christians & Williams (2001) have stated that a positive relationship exists between albumen content of the egg and oviduct mass.

Table 4.4 Mean and standard errors of the physical components and the albumen to yolk ratio of ostrich eggs produced by females given diets varying in ME content

Diet (MJ ME/kg feed)	Egg weight (g)	Albumen weight (g)	Yolk weight (g)	Shell weight (g)	A:Y
7.5	1421.9 ^a	792.2 ^a	330.5 ^a	286.6 ^a	2.41 ^a
8.0	1450.5 ^a	764.5 ^a	333.2 ^a	295.6 ^a	2.34 ^a
8.5	1361.4 ^a	736.8 ^a	351.7 ^a	275.4 ^a	2.10 ^a
9.0	1373.7 ^a	745.7 ^a	312.6 ^a	274.4 ^a	2.41 ^a
9.5	1407.3 ^a	784.7 ^a	342.9 ^a	288.4 ^a	2.31 ^a
10.0	1326.7 ^a	705.2 ^a	342.6 ^a	276.7 ^a	2.10 ^a
Standard error	34.6	35.5	14.0	8.7	0.1

^{a,b} means in columns with different superscripts differ significantly (P<0.05)

It is of interest to see is that the mass of eggs increased (P<0.05) for the number of the egg in the laying cycle, which is similar to results obtained with poultry. The increase is linear ($y = 3.1x + 1281.1$; SEest = 32.3; $R^2 = 0.16$). The weight of the albumen and yolk also increased significantly (P<0.05). These egg components' increase was also linear ($y = 2.0x + 692.5$; SEest = 23.4; $R^2 = 0.13$; $y = 0.68x + 314.7$; SEest = 9.5; $R^2 = 0.09$; respectively for albumen and yolk). Larger eggs have a greater proportion of albumen in laying hens (Hussein *et al.*, 1993; Suk & Park, 2001). This study reveals that egg weight is also significantly correlated ($r>0.5$; P<0.05) with shell, albumen and yolk weight. The increase in the weight of the eggshell for the number of the egg in the laying cycle was statistically significant (P<0.05). The slope of the linear regression was significant ($y = 0.35x + 272.1$; SEest = 6.0; P<0.05; $R^2 = 0.06$). Table 4.5 provides the weight of the shell, albumen, and yolk.

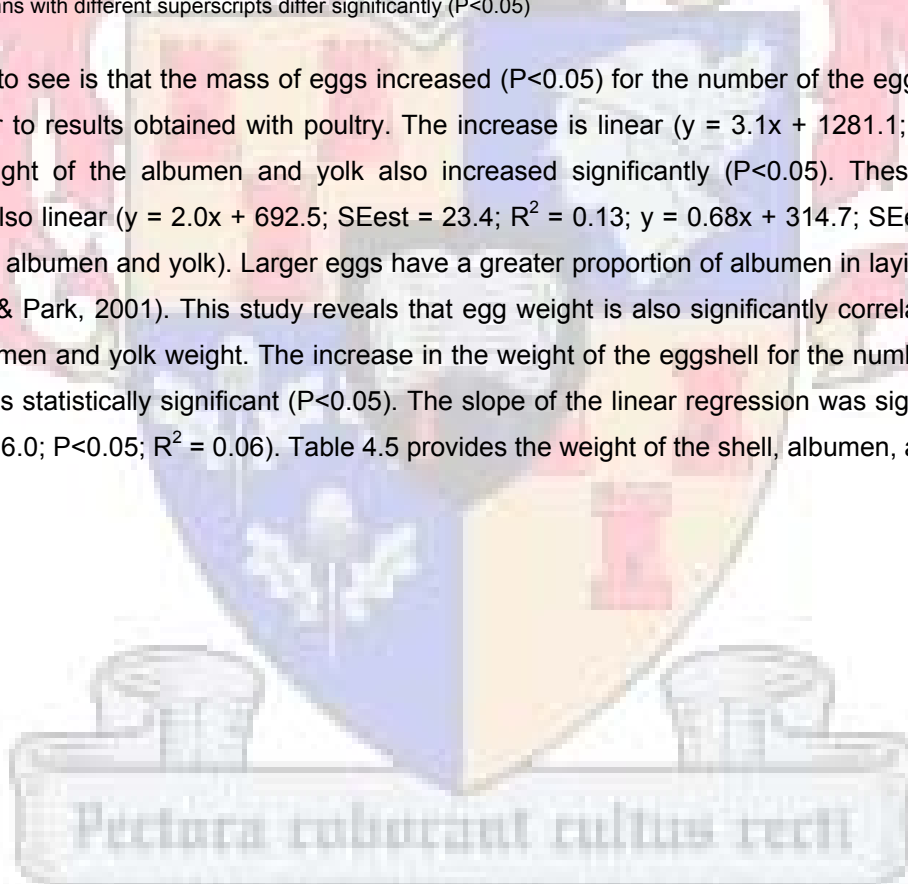


Table 4.5 Weight of the physical components of ostrich eggs for the number of the egg in the laying cycle

	Category 1 ¹	Category 2 ²	Category 3 ³	Category 4 ⁴	Category 5 ⁵	Category 6 ⁶	se ⁷
Egg weight	1301.4 ^a	1380.6	1378.2	1427.9	1486.1	1532.8 ^b	59.0
Eggshell weight	270.7 ^a	286.9	289.9	286.2	297.7	287.7 ^b	11.0
Albumen weight	703.8 ^a	765.1	752.8	777.2	847.3	852.7 ^b	41.4
Yolk weight	326.1 ^a	324.8	332.5	360.5	338.8	391.0 ^b	14.3

^{a,b} : means in rows with different superscript differ significantly (P<0.05)

¹Category 1: the first 15 eggs of the laying cycle

²Category 2: the second 15 eggs of the laying cycle

³Category 3: the third 15 eggs of the laying cycle

⁴Category 4: the fourth 15 eggs of the laying cycle

⁵Category 5: the fifth 15 eggs of the laying cycle

⁶Category 6: the last 15 eggs of the laying cycle

⁷se=standard error

Dietary fat can elevate egg and albumen weight in laying hens (Whitehead *et al.*, 1991). It is possible that dietary fatty acids like linolenic acid can have a stimulatory effect on oviducal protein secretion. Oestrogen regulates the synthesis of most oviduct proteins, and the working mechanisms of oestrogen can possibly be influenced by dietary fatty acids. It can be speculated that linolenic acid stimulates oviducal protein secretion in the breeding female ostrich, although the evidence in this experiment does not support this theory. In addition, the increase in the crude protein content of eggs over the season can possibly also be ascribed to higher circulating levels of oestrogen. Previous research has shown that dietary methionine (Carey *et al.*, 1991; Shafer *et al.*, 1998) significantly affects the weight of the yolk and albumen in laying hens; and lysine (Prochaska *et al.*, 1996) the albumen weight. Albumen and yolk protein content are also elevated by dietary methionine (Shafer *et al.*, 1996) and lysine (Prochaska *et al.*, 1996). Novak *et al.* (2004) reported a significant two-way interaction between total sulfur amino acids and lysine for % albumen and % yolk proteins.

ANOVA revealed no difference (P>0.05) between the diets for the albumen to yolk ratio (A:Y). Mean A:Y ratio were 2.29±0.1. ANACOVA, when number of the egg in laying cycle was held as the covariate, revealed no significant influence on the A:Y ratio.

Tables 4.6 and 4.7 provide respectively the mean and standard error of the nutrient and calcium and trace element content of the egg white and yolk mixture resulting from the different experimental diets. Table 4.8 reports the amino acid composition of the egg white and yolk mixture resulting from the different experimental diets. No significant differences (P>0.05) for crude protein (126.9±4.7g) and fat content (89.7.1±4.2g) of the egg on an as is basis were seen amongst the different diets. No linear tendency in the crude protein content of eggs amongst the treatments were seen, but the opposite is true for fat content ($y = 2.6x + 80.5$; SEest = 3.7; R² = 0.1).

Table 4.6 Mean and standard errors of the nutrient content of the egg white and yolk mixture produced by females given diets varying in ME content

Diet (MJ ME/kg feed)	Crude protein (g)	Fat/ether extract (g)	C18:3n-3 (linolenic acid) (%)	Moisture (%)	Ash (%)
7.5	131.0 ^a	90.4 ^a	1.4 ^a	78.0	4.20
8.0	128.4 ^a	91.6 ^a	2.6 ^{ab}	77.6	4.10
8.5	125.8 ^a	94.0 ^a	3.9 ^b	77.6	4.00
9.0	121.4 ^a	83.7 ^a	4.1 ^b	78.3	4.10
9.5	130.9 ^a	90.0 ^a	3.6 ^{ab}	77.8	4.00
10.0	124.3 ^a	88.8 ^a	4.2 ^b	77.4	4.00
Standard error	4.7	4.2	0.6		

^{a,b} means in columns with different superscripts differ significantly (P<0.05)
^{*} crude protein and fat expressed on an as-is basis

Linolenic acid content (C18:3n-3) of the eggs increased linearly ($y = 0.49x + 1.5$; SEest = 1.57; $R^2 = 0.23$; $P < 0.05$) and was significant different amongst the dietary treatments. See Figure 6. Sussi *et al.* (2003) found significant differences in the linolenic acid content of eggs amongst treatments when the diets were supplemented with 3% and 6% linseed oil, although the inclusion rate had no effect on production data. Di Meo *et al.* (2003) reported high variation within groups, similar to the present study. The authors suggested that the egg-laying period has little effect on the deposition of fatty acids, although this was not seen in the present study. In poultry it is possible for n-3 unsaturated fatty acids to be deposited in the egg or meat products (Caston and Leeson, 1990; Ajuyah *et al.*, 1991; Aymond and Van Elswyk, 1995) and edible tissues (Phetteplace and Watkins, 1989). Lower n-3 fatty acids in the eggs of farmed ostriches result in lower hatchability, as observed in a study by Noble *et al.* (1996). Wang *et al.* (2000) reported a higher concentration of immunoglobulins in the egg yolk by feeding laying hens a diet rich in n-3 polyunsaturated fatty acids. Linseed is an excellent source of C18:3n-3 fatty acids and can be used in ostrich breeder diets for the transfer of C18:3n-3 fatty acids to eggs. Animals cannot produce essential n-3 fatty acids *de novo* (van Elswyk, 1997), and the dietary inclusion of a raw material rich in essential fatty acids seems prudent. Linolenic acid (C18:3n-3) are the only omega 3-fatty acids that are transferred in high quantities to the egg when linseed is fed, since the oil contains about 56% C18:3n-3 and not any other omega 3-fatty acid (Phetteplace and Watkins, 1989). Very low quantities of the other omega 3-fatty acids were detected in the eggs and are probably a metabolic derivative of C18:3n-3 (van Elswyk, 1997). Van Elswyk (1997) stated for fowl eggs that the longer polyunsaturated fatty acids are deposited in limited amounts regardless of the form of the linseed. Superchi *et al.* (2002) stated that a good supply of essential fatty acids is more important than the total amount of lipid supplied by the parent bird.

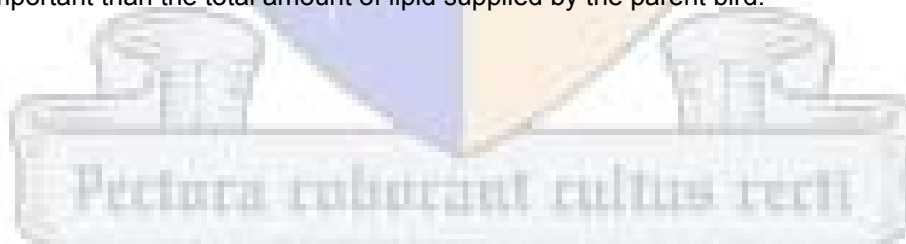


Table 4.7 Mean and standard errors of the calcium and trace element content of the egg white and yolk mixture produced by females given diets varying in ME content

Diet MJ ME/kg feed	Calcium (%)	Phosphorus (%)	Potassium (%)	Magnesium (%)	Iron (mg/kg)	Copper (mg/kg)	Zinc (mg/kg)	Manganese (mg/kg)	Boron (mg/kg)	Sodium (mg/kg)
7.5	0.30 ^a	0.81 ^a	0.55 ^a	0.8 ^a	102.5 ^a	5.2 ^a	46.2 ^a	0.9 ^a	1.7 ^a	7633.3 ^a
8.0	0.30 ^a	0.81 ^a	0.54 ^a	0.8 ^a	102.8 ^a	6.2 ^a	46.7 ^a	0.9 ^a	1.6 ^a	7583.3 ^a
8.5	0.28 ^a	0.85 ^b	0.54 ^a	0.8 ^a	100.6 ^a	5.3 ^a	48.5 ^a	0.9 ^a	1.6 ^a	7033.3 ^a
9.0	0.28 ^a	0.81 ^a	0.54 ^a	0.8 ^a	107.2 ^a	4.7 ^a	45.8 ^a	0.8 ^a	1.6 ^a	7850.0 ^a
9.5	0.30 ^a	0.83 ^a	0.55 ^a	0.8 ^a	110.3 ^a	5.5 ^a	46.9 ^a	0.8 ^a	1.3 ^a	7566.7 ^a
10.0	0.30 ^a	0.85 ^b	0.54 ^a	0.8 ^a	112.6 ^a	5.9 ^a	49.4 ^a	0.8 ^a	1.6 ^a	7291.7 ^a
Standard error	0.01	0.01	0.008	0.002	5.8	0.8	1.4	0.04	0.1	294.5

^{a,b} means in columns with different superscripts differ significantly ($P < 0.05$)

* values expressed on an as is basis

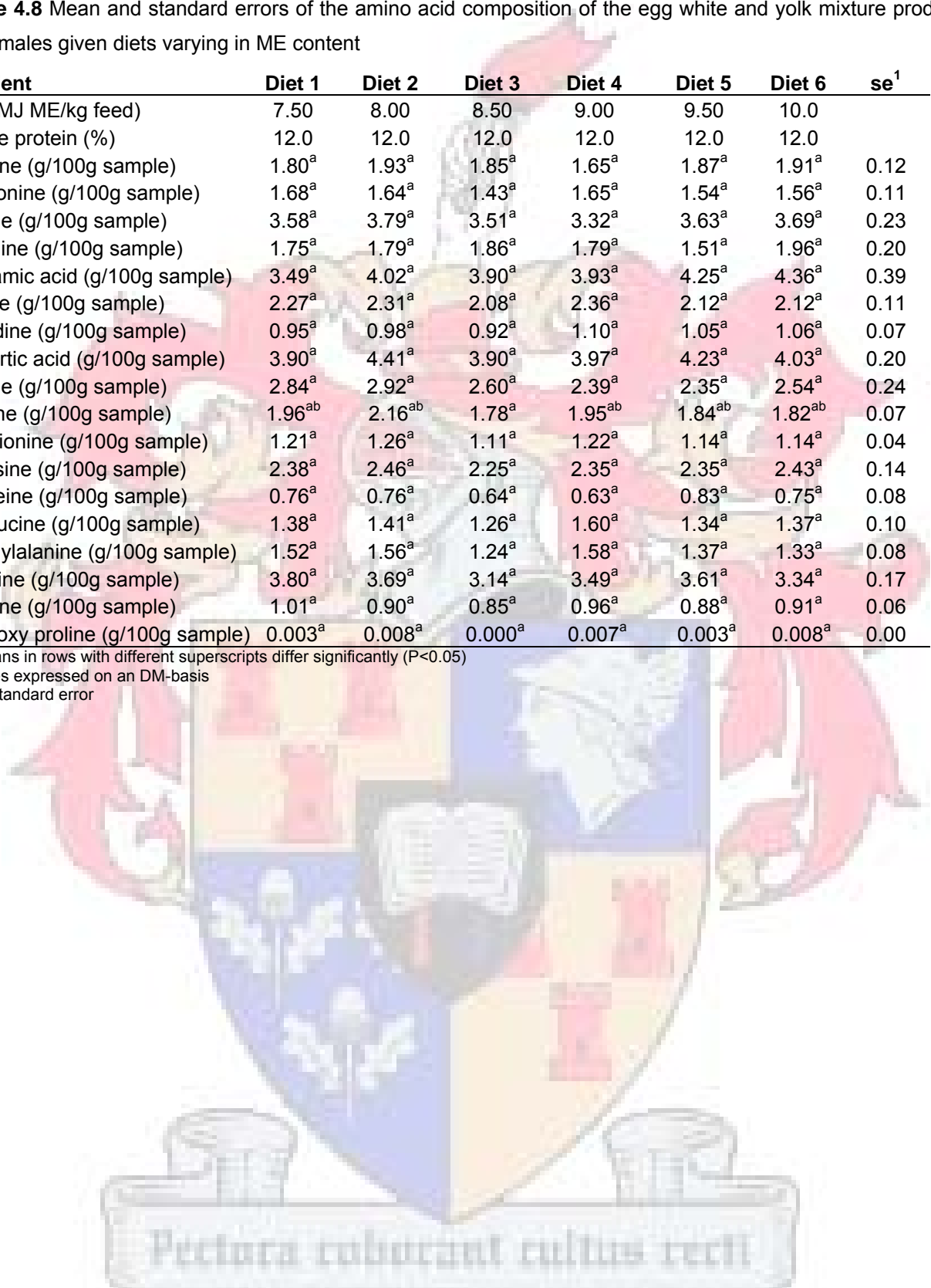
Table 4.8 Mean and standard errors of the amino acid composition of the egg white and yolk mixture produced by females given diets varying in ME content

Nutrient	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	se ¹
ME (MJ ME/kg feed)	7.50	8.00	8.50	9.00	9.50	10.0	
Crude protein (%)	12.0	12.0	12.0	12.0	12.0	12.0	
Alanine (g/100g sample)	1.80 ^a	1.93 ^a	1.85 ^a	1.65 ^a	1.87 ^a	1.91 ^a	0.12
Threonine (g/100g sample)	1.68 ^a	1.64 ^a	1.43 ^a	1.65 ^a	1.54 ^a	1.56 ^a	0.11
Serine (g/100g sample)	3.58 ^a	3.79 ^a	3.51 ^a	3.32 ^a	3.63 ^a	3.69 ^a	0.23
Arginine (g/100g sample)	1.75 ^a	1.79 ^a	1.86 ^a	1.79 ^a	1.51 ^a	1.96 ^a	0.20
Glutamic acid (g/100g sample)	3.49 ^a	4.02 ^a	3.90 ^a	3.93 ^a	4.25 ^a	4.36 ^a	0.39
Valine (g/100g sample)	2.27 ^a	2.31 ^a	2.08 ^a	2.36 ^a	2.12 ^a	2.12 ^a	0.11
Histidine (g/100g sample)	0.95 ^a	0.98 ^a	0.92 ^a	1.10 ^a	1.05 ^a	1.06 ^a	0.07
Aspartic acid (g/100g sample)	3.90 ^a	4.41 ^a	3.90 ^a	3.97 ^a	4.23 ^a	4.03 ^a	0.20
Lysine (g/100g sample)	2.84 ^a	2.92 ^a	2.60 ^a	2.39 ^a	2.35 ^a	2.54 ^a	0.24
Proline (g/100g sample)	1.96 ^{ab}	2.16 ^{ab}	1.78 ^a	1.95 ^{ab}	1.84 ^{ab}	1.82 ^{ab}	0.07
Methionine (g/100g sample)	1.21 ^a	1.26 ^a	1.11 ^a	1.22 ^a	1.14 ^a	1.14 ^a	0.04
Tyrosine (g/100g sample)	2.38 ^a	2.46 ^a	2.25 ^a	2.35 ^a	2.35 ^a	2.43 ^a	0.14
Cysteine (g/100g sample)	0.76 ^a	0.76 ^a	0.64 ^a	0.63 ^a	0.83 ^a	0.75 ^a	0.08
Isoleucine (g/100g sample)	1.38 ^a	1.41 ^a	1.26 ^a	1.60 ^a	1.34 ^a	1.37 ^a	0.10
Phenylalanine (g/100g sample)	1.52 ^a	1.56 ^a	1.24 ^a	1.58 ^a	1.37 ^a	1.33 ^a	0.08
Leucine (g/100g sample)	3.80 ^a	3.69 ^a	3.14 ^a	3.49 ^a	3.61 ^a	3.34 ^a	0.17
Glycine (g/100g sample)	1.01 ^a	0.90 ^a	0.85 ^a	0.96 ^a	0.88 ^a	0.91 ^a	0.06
Hydroxy proline (g/100g sample)	0.003 ^a	0.008 ^a	0.000 ^a	0.007 ^a	0.003 ^a	0.008 ^a	0.00

^{ab} means in rows with different superscripts differ significantly (P<0.05)

^{*} values expressed on an DM-basis

¹ se=standard error



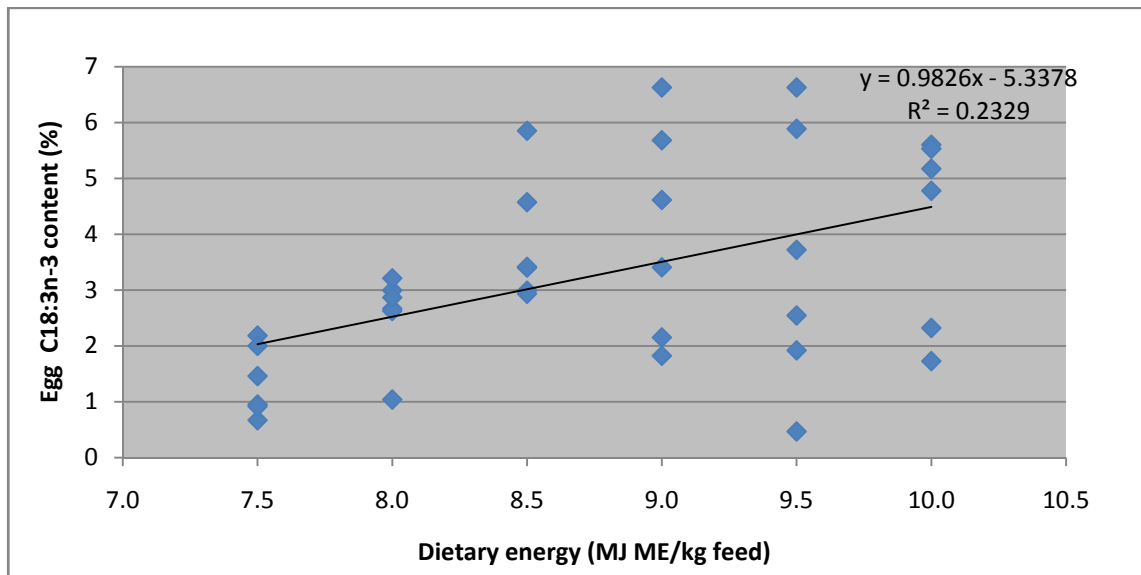
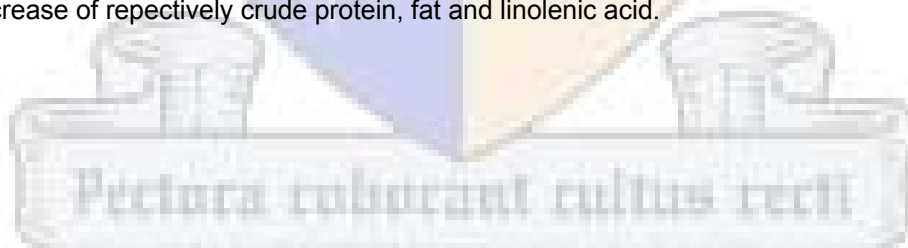


Figure 6 C18:3n-3 (linolenic acid) content of ostrich eggs from birds fed the different experimental diets varying in metabolisable energy content

The only significant differences ($P < 0.05$) amongst the treatments were seen for proline. A tendency was noticed for methionine, alanine and phenylalanine ($P \geq 0.05$).

The crude protein and fat content of eggs sampled at different times during the season differ significantly ($P < 0.05$). Superchi *et al.* (2002) observed that significantly more crude protein is deposited in ostrich eggs as the laying period progressed. The linear regression model reveals that there is a linear increase in the crude protein and fat content of ostrich eggs when eggs are laid towards the end of the laying cycle ($y = 0.25x + 119.1$; $SE_{est} = 3.0$; $R^2 = 0.12$; $P < 0.05$; $y = 0.18x + 84$; $SE_{est} = 2.8$; $R^2 = 0.08$; $P < 0.05$; respectively for crude protein and fat). This increase in crude protein and fat in eggs laid later in the laying cycle can be a natural occurrence in ostriches due to seasonal effects and cannot be ascribed to dietary effects. The possibility exists that the requirement for egg formation increased during the clutches that are laid toward the end of the laying cycle. The higher proportion of albumen and yolk in eggs over the breeding season is therefore explained by higher accretion of crude protein and fat in the eggs as the season progresses. Eggs sampled at different times during the season contained more linolenic acid ($P < 0.05$) ($y = 0.02x + 2.54$; $SE_{est} = 0.5$; $R^2 = 0.04$; $P < 0.05$). Figures 7-9 shows the increase of respectively crude protein, fat and linolenic acid.



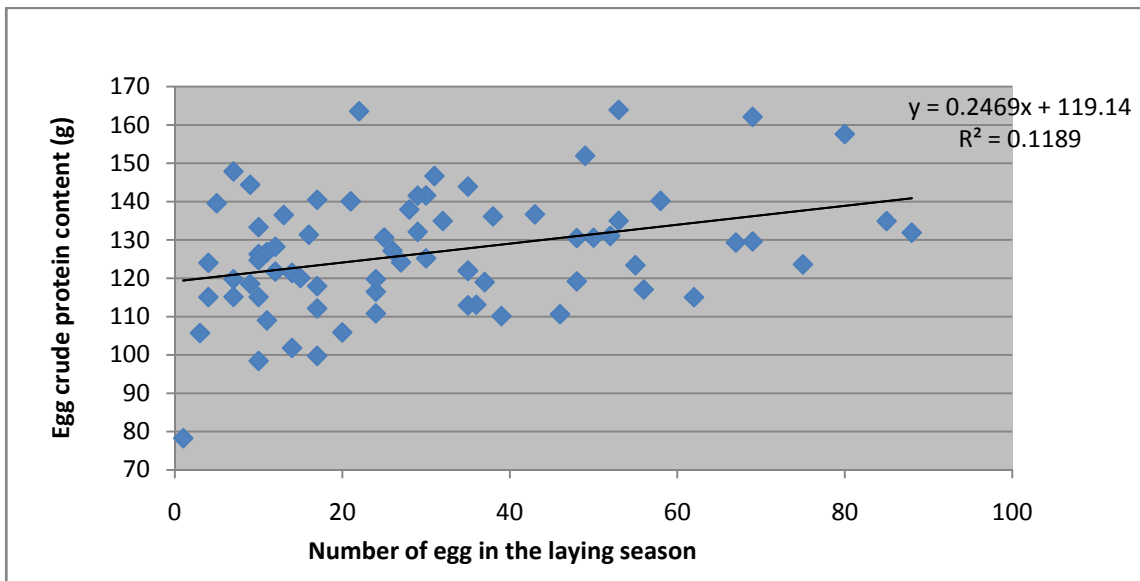


Figure 7 Crude protein content of eggs for the number of the egg in the laying cycle

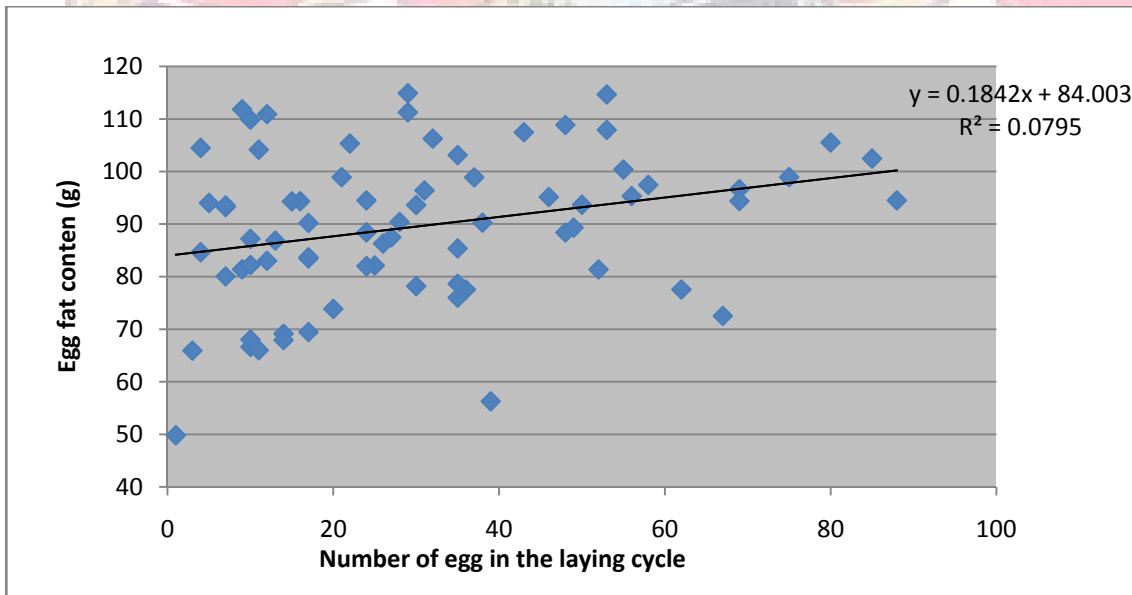
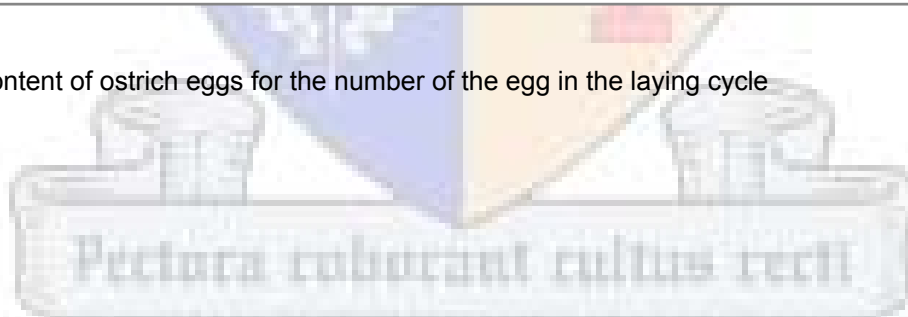


Figure 8 Fat content of ostrich eggs for the number of the egg in the laying cycle



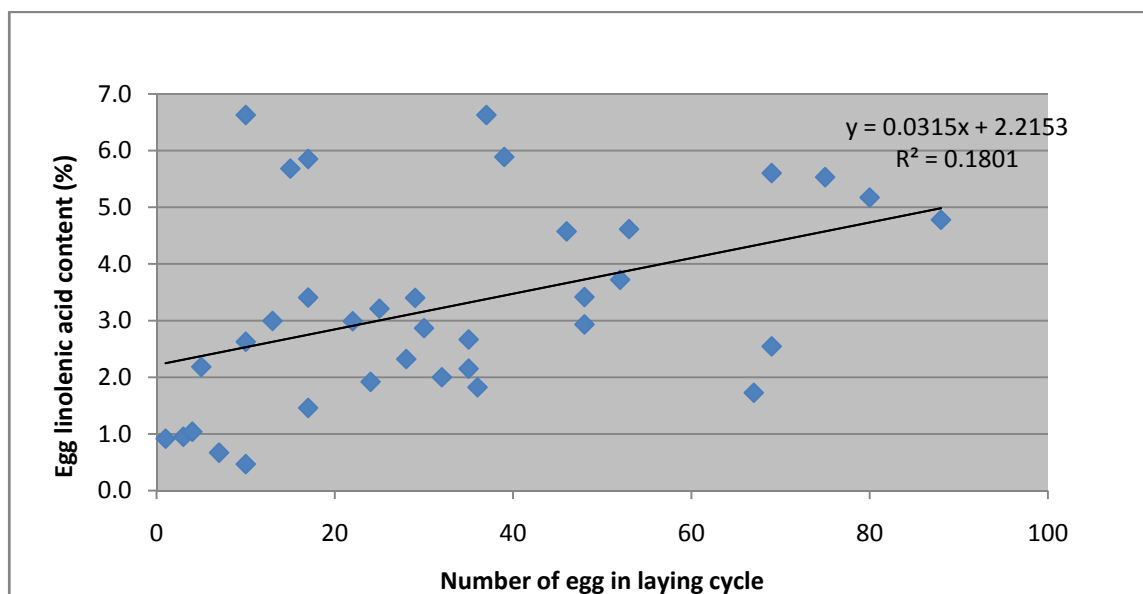


Figure 9 C18:3n-3 (linolenic acid) content of ostrich eggs for the number of the egg in the laying cycle

Analysis of covariance, when the number of the egg in the laying cycle was held as the covariate, revealed that lysine, proline, tyrosine and cysteine differed ($P < 0.05$) amongst the number of the egg in the laying cycle. Valine tended to change ($P \geq 0.05$). The amino acid content of the number of the egg in the laying cycle is listed in Table 4.10.

Analysis of covariance (ANACOVA), with age in years as the covariate, revealed that age had no effect ($P > 0.05$) on any of the variables in Table 4.9.

Table 4.9 Physical components, nutrient content and albumen to yolk ratio of eggs produced by female breeding birds of different ages (years)

age	n ¹	egg weight (g)	eggshell weight (g)	yolk weight (g)	albumen weight (g)	protein (g)	fat (g)	A:Y
2	4	1361.9 ^a	276.0 ^a	321.8 ^a	759.2 ^a	126.0 ^a	87.5 ^a	2.41 ^a
3	27	1348.2 ^a	276.8 ^a	332.9 ^a	734.2 ^a	123.9 ^a	89.7 ^a	2.23 ^a
4	17	1385.7 ^a	283.4 ^a	338.5 ^a	763.3 ^a	126.5 ^a	89.0 ^a	2.28 ^a
5	1	908.5 ^a	253.1 ^a	205.2 ^a	450.2 ^a	78.3 ^a	49.8 ^a	2.19 ^a
6	11	1479.7 ^a	301.5 ^a	340.7 ^a	835.1 ^a	138.5 ^a	91.2 ^a	2.47 ^a
7	4	1314.9 ^a	281.8 ^a	301.7 ^a	729.8 ^a	118.6 ^a	85.5 ^a	2.46 ^a
8	5	1305.3 ^a	271.3 ^a	352.8 ^a	680.3 ^a	122.5 ^a	90.5 ^a	1.99 ^a
9	2	1709.5 ^a	327.9 ^a	424.6 ^a	955.2 ^a	160.7 ^a	110.1 ^a	2.25 ^a
12	1	1265.0 ^a	262.5 ^a	358.4 ^a	643.7 ^a	130.5 ^a	108.9 ^a	1.80 ^a
se		36.0	6.3	13.1	35.3	3.1	3.7	0.1

^a crude protein and fat expressed on an as-is basis

¹ n = number of females

^{a,b}: means in columns with different superscript differ significantly ($P < 0.05$)

A tendency for differences ($P \geq 0.05$) between age groups were noticed for valine, proline and methionine. The amino acid content of the different age groups is listed in Table 4.11.

An evaluation of the egg-shells for calcium content was made. The content (%) did not differ between the treatments, nor for the content of the number of the egg in the laying cycle ($P > 0.05$). Table 4.12 shows the calcium and trace element content of the shells. Almeida Paz *et al.* (2008) were able to increase the weight of ostrich eggs by feeding a diet high in calcium. For hens, Clunies *et al.* (1992) were able to increase egg-shell weight and gram calcium in the shell with higher dietary calcium levels and, concluded that calcium intake must be increased to improve the quality of egg-shells. The data from Clunies *et al.* (1992) suggests that dietary calcium is not the only factor involved in shell quality, but also that the ability of the shell gland (uterus) to increase the rate of shell secretion is important. Dietary calcium has a significant effect on the shell weight and calcium content of the shell in broiler breeders (Sooncharenying & Edwards, 1989). Ca^{2+} is also utilized by avian embryos from the egg-shell (Parkard & Parkard, 1984; Simkiss, 1991; Tuan *et al.* 1991) in physiological processes (Bronner & Stein, 1992).

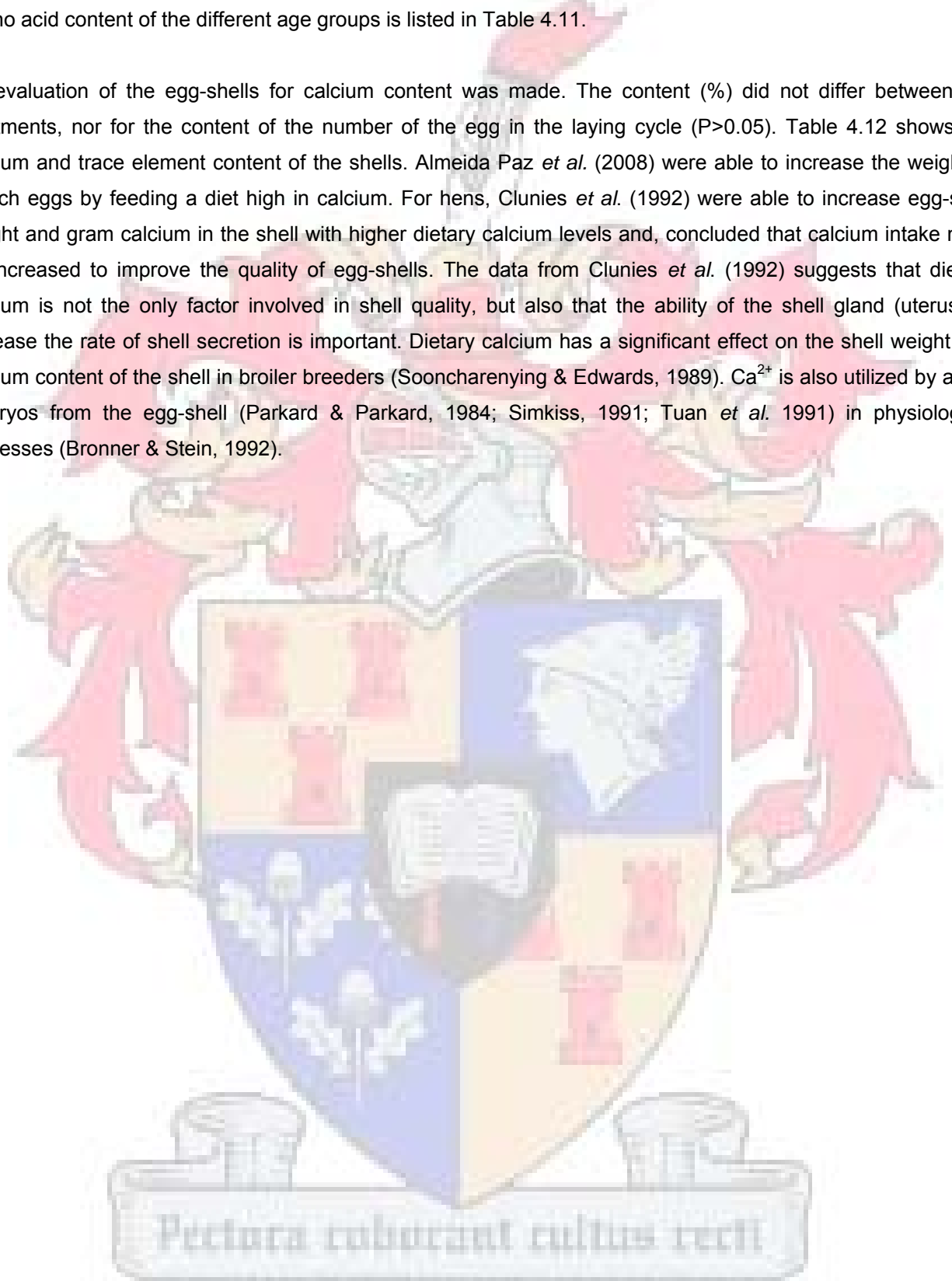


Table 4.10 Amino acid composition of ostrich eggs for the number of the egg in the laying cycle

Amino acid	Alanine	Threonine	Serine	Arginine	Glutamic acid	Valine	Histidine	Aspartic acid	Lysine
Category 1 ¹	1.78 ^a	1.54 ^a	3.51 ^a	1.78 ^a	3.98 ^a	2.18 ^a	0.99 ^a	4.07 ^a	2.31 ^a
Category 2 ²	1.74	1.62	3.39	1.58	3.40	2.13	0.95	3.93	2.50
Category 3 ³	2.02	1.89	4.14	2.32	4.95	2.30	1.02	4.28	2.83
Category 4 ⁴	1.70	1.61	3.47	1.59	4.04	2.14	1.04	3.83	2.88
Category 5 ⁵	2.01	1.62	3.83	1.91	4.36	2.31	1.02	4.32	3.14
Category 6 ⁶	2.09 ^a	1.39 ^a	3.87 ^a	1.91 ^a	3.94 ^a	2.27 ^a	1.10 ^a	4.20 ^a	2.67 ^b
se	0.12	0.11	0.23	0.20	0.39	0.11	0.07	0.20	0.24

Amino acid	Proline	Methionine	Tyrosine	Cysteine	Isoleucine	Phenylalanine	Leucine	Glycine	Hydroxy proline
Category 1 ¹	1.88 ^a	1.19 ^a	2.27 ^a	0.61 ^a	1.38 ^a	1.41 ^a	3.43 ^a	0.91 ^a	0.004 ^a
Category 2 ²	1.86	1.15	2.35	0.85	1.34	1.59	3.79	0.98	0.005
Category 3 ³	1.91	1.15	2.31	0.75	1.50	1.29	3.42	1.07	0.000
Category 4 ⁴	1.87	1.09	2.27	0.73	1.31	1.32	3.31	0.87	0.000
Category 5 ⁵	2.09	1.25	2.59	0.81	1.45	1.48	3.63	0.95	0.008
Category 6 ⁶	1.92 ^b	1.17 ^a	2.62 ^b	0.89 ^b	1.41 ^a	1.26 ^a	3.46 ^a	0.78 ^a	0.000 ^a
se	0.07	0.04	0.14	0.08	0.10	0.08	0.17	0.06	0.000

^{a,b} : means in columns with different superscript differ significantly (P<0.05)

^aamino acid values expressed on an DM-basis

¹Category 1: the first 15 eggs of the laying cycle

²Category 2: the second 15 eggs of the laying cycle

³Category 3: the third 15 eggs of the laying cycle

⁴Category 4: the fourth 15 eggs of the laying cycle

⁵Category 5: the fifth 15 eggs of the laying cycle

⁶Category 6: the last 15 eggs of the laying cycle

Table 4.11 Amino acid composition of eggs produced by female breeding birds of different ages

Age	n	Alanine	Threonine	Serine	Arginine	Glutamic acid	Valine	Histidine	Aspartic acid	Lysine
2	1	1.49 ^a	1.76 ^a	3.35 ^a	1.78 ^a	4.93 ^a	1.94 ^a	0.98 ^a	4.30 ^a	2.11 ^a
3	10	1.83 ^a	1.51 ^a	3.55 ^a	1.80 ^a	3.84 ^a	2.22 ^a	1.02 ^a	3.90 ^a	2.51 ^a
4	6	1.73 ^a	1.54 ^a	3.33 ^a	1.64 ^a	3.59 ^a	2.05 ^a	0.96 ^a	3.90 ^a	2.49 ^a
6	3	2.11 ^a	1.72 ^a	4.18 ^a	2.07 ^a	4.55 ^a	2.44 ^a	0.94 ^a	4.72 ^a	3.52 ^a
7	1	1.73 ^a	1.78 ^a	3.43 ^a	1.02 ^a	4.00 ^a	2.31 ^a	1.12 ^a	4.25 ^a	1.96 ^a
8	1	2.02 ^a	1.89 ^a	4.14 ^a	2.32 ^a	4.95 ^a	2.30 ^a	1.02 ^a	4.28 ^a	2.83 ^a
9	1	2.13 ^a	1.39 ^a	3.82 ^a	1.63 ^a	4.32 ^a	2.29 ^a	1.20 ^a	4.32 ^a	2.64 ^a
se		0.12	0.11	0.23	0.20	0.39	0.11	0.07	0.20	0.24

Age	n	Proline	Methionine	Tyrosine	Cysteine	Isoleucine	Phenylalanine	Leucine	Glycine	Hydroxy proline
2	1	2.03 ^a	1.23 ^a	2.16 ^a	0.43 ^a	1.27 ^a	1.38 ^a	2.96 ^a	0.91 ^a	0.010 ^a
3	10	1.83 ^a	1.14 ^a	2.38 ^a	0.74 ^a	1.38 ^a	1.38 ^a	3.43 ^a	0.90 ^a	0.002 ^a
4	6	1.84 ^a	1.15 ^a	2.27 ^a	0.72 ^a	1.32 ^a	1.50 ^a	3.62 ^a	0.92 ^a	0.005 ^a
6	3	2.25 ^a	1.32 ^a	2.65 ^a	0.87 ^a	1.53 ^a	1.55 ^a	3.84 ^a	0.97 ^a	0.007 ^a
7	1	2.11 ^a	1.25 ^a	1.99 ^a	0.34 ^a	1.32 ^a	1.46 ^a	3.35 ^a	0.95 ^a	0.010 ^a
8	1	1.91 ^a	1.15 ^a	2.31 ^a	0.75 ^a	1.50 ^a	1.29 ^a	3.42 ^a	1.07 ^a	0.010 ^a
9	1	1.98 ^a	1.19 ^a	2.75 ^a	0.96 ^a	1.42 ^a	1.26 ^a	3.56 ^a	0.74 ^a	0.000 ^a
se		0.07	0.04	0.14	0.08	0.10	0.08	0.17	0.06	0.00

^{a,b}: means in columns with different superscript differ significantly (P<0.05)

^{*}amino acid values expressed on an DM-basis

n=number of eggs

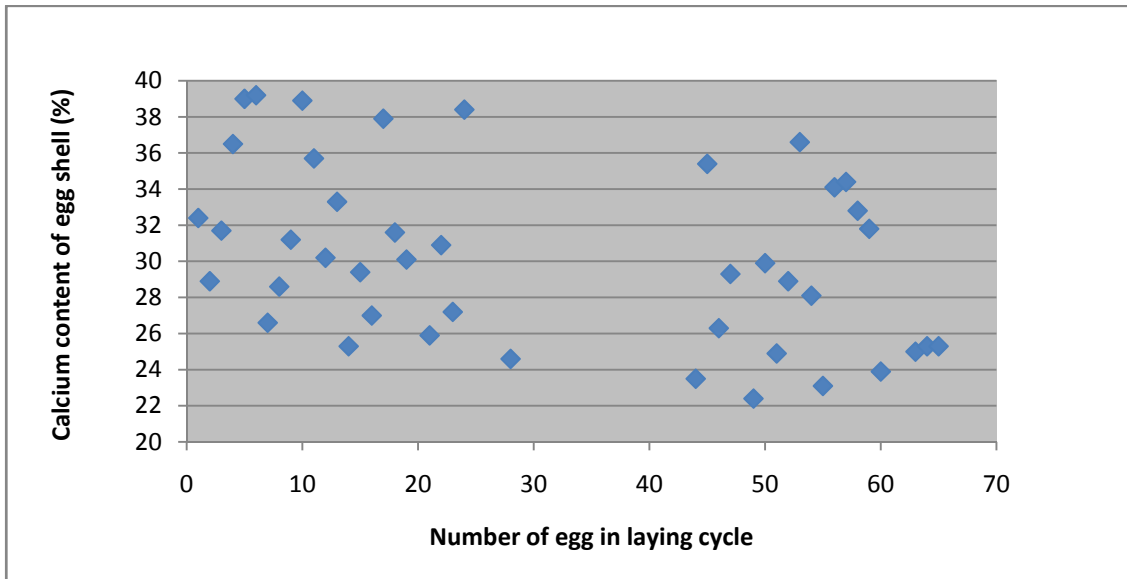


Figure 10 Calcium content (%) of ostrich egg-shells for the number of the egg in the laying cycle

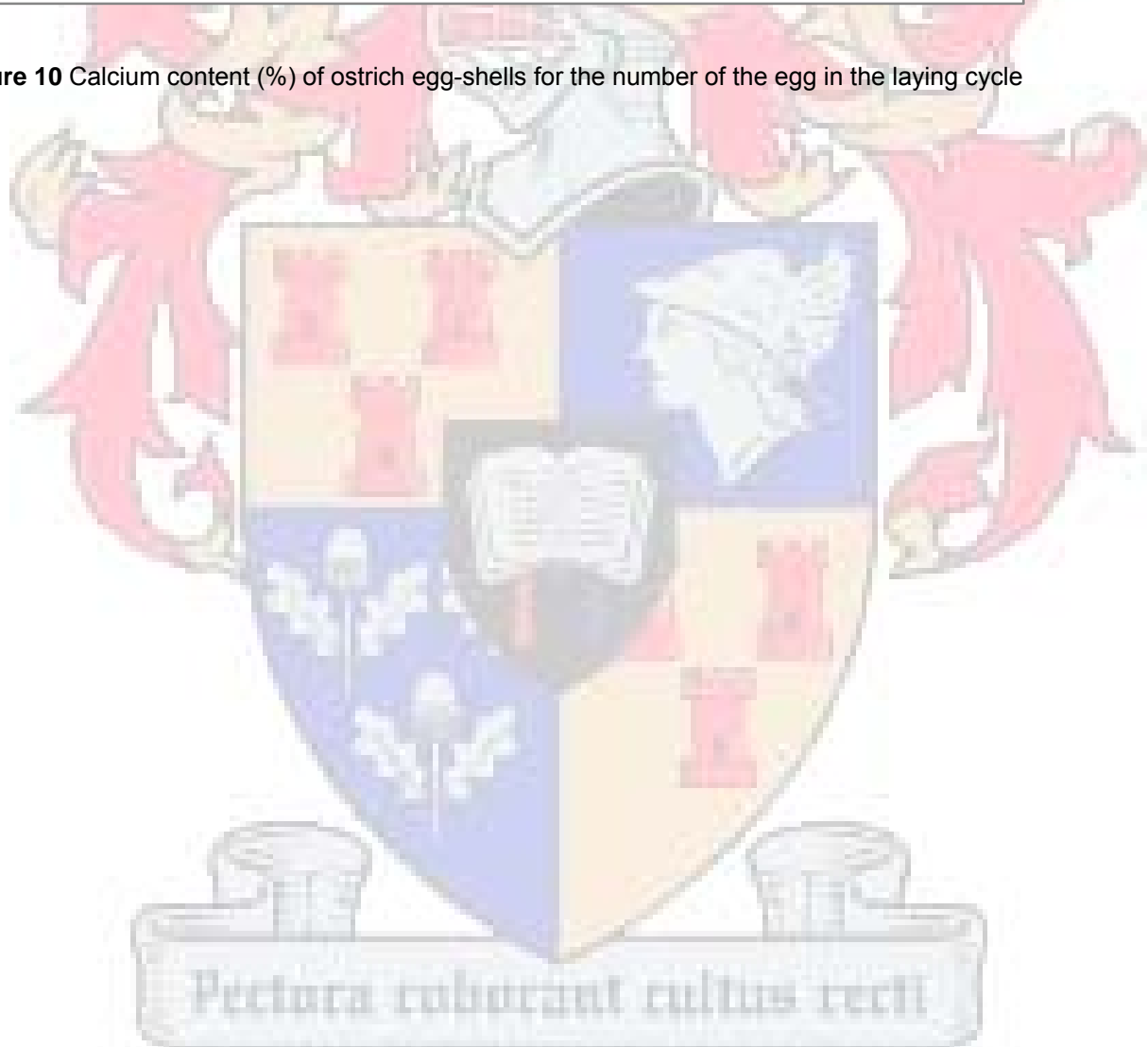


Table 4.12 Mean and standard errors of the calcium and trace element content of the eggshell from females fed experimental diets varying in ME content

Diet (MJ ME/kg feed)	Calcium (%)	Phosphorus (%)	Potassium (%)	Magnesium (%)	Iron (mg/kg)	Copper (mg/kg)	Zinc (mg/kg)	Manganese (mg/kg)	Boron (mg/kg)	Sodium (mg/kg)
7.5	29.0 ^a	0.04 ^a	0.02 ^a	0.1 ^a	3.3 ^a	0.1 ^a	3.00 ^a	0.1 ^a	0.3 ^a	812.0 ^a
8.0	30.1 ^a	0.02 ^a	0.03 ^a	0.1 ^a	2.6 ^a	0.0 ^a	2.90 ^a	0.1 ^a	0.2 ^a	752.2 ^a
8.5	28.6 ^a	0.03 ^a	0.03 ^a	0.1 ^a	4.0 ^a	0.2 ^a	3.10 ^a	0.1 ^a	0.2 ^a	822.9 ^a
9.0	29.7 ^a	0.03 ^a	0.03 ^a	0.1 ^a	1.7 ^a	0.0 ^a	2.10 ^a	0.1 ^a	0.2 ^a	798.6 ^a
9.5	31.6 ^a	0.03 ^a	0.03 ^a	0.1 ^a	2.7 ^a	0.0 ^a	13.80 ^a	0.1 ^a	0.2 ^a	756.7 ^a
10.0	32.0 ^a	0.02 ^a	0.03 ^a	0.1 ^a	1.5 ^a	0.0 ^a	2.70 ^a	0.1 ^a	0.2 ^a	794.4 ^a
se	1.9	0.003	0.002	0.006	0.9	0.03	2.5	0.0	0.02	37.7

^{a,b} means in columns with different superscripts differ significantly (P<0.05)

* values expressed on an as is basis

Conclusion

The results from this study indicated that dietary energy does not interfere with the production performance of breeding ostriches if the daily energy allotment exceeds 25.5 MJ ME per bird per day. Previous studies revealed that a daily ration below 22 MJ ME per bird per day will probably result in lower egg production (Brand *et al.*, 2003). A ration formulated to provide an energy intake of between 22 and 25.5 MJ ME and per bird per day seems therefore to be the most economical option for feeding breeding ostriches with the above-mentioned production levels (Brand, 2008). This study confirms that dietary energy content did not affect the chemical composition of the eggs. The protein, fat and linolenic acid content of eggs increased for the number of the egg in the laying cycle, stating that the nutrient costs for egg formation as more eggs are laid during a single laying cycle possibly increased. There was no relationship between the nutrient content of the diet and the reproductive performance of the birds, which is in agreement with Brand (2002).

References

- Ajuyah, A.O., Lee, K.H., Hardin, R.T. & Sim, J.S., 1991. Changes in the yield and in the fatty acid composition of whole carcass and selected meat portions of broiler chickens fed full-fat oil seeds. *Poult Sci.* 70, 2304-2314
- ALASA, 1998. ALASA handbook of feeds and plant analysis. 1. Pretoria, South Africa, Agricultural Laboratory Association of Southern Africa
- Almeida Paz, I.C.L., Mendes, A.A., Balog, A., Komiyama, C.M., Almeida, I.C.L. & Milbradt, E.L., 2008. Bone and egg quality of breeder ostriches fed a maintenance diet (low calcium) and a layer diet (high calcium). 4th Ratite Sci. Sym, 29 June - 4 July 2008, Brisbane, Australia
- Aymond, W.M. & Van Elswyk, M.E., 1995. Yolk thiobarbituric acid reactive substances and n-3 fatty acids in response to whole and ground flaxseed. *Poult.Sci.* 74, 1388-1394
- Brand, T.S., 2008. *Volstruisvoeding: 'n Wetenskaplike benadering*. Sun Print, University of Stellenbosch, Stellenbosch. pp. 48
- Brand, T.S. & Gous, R.M., 2006. Feeding Ostriches. In: *Feeding in domestic vertebrates: From structure to behaviour*. Ed. Bels, V., CAB International, Wallingford, England. pp. 136-155
- Brand, Z., 2002. The effect of energy and protein nutritional levels on production of breeding ostriches. MSc Thesis. Rhodes University, South Africa
- Brand, Z., Brand, T.S. & Brown, C.R., 2002. The effect of dietary and protein levels during a breeding season of ostriches (*Struthio camelus domesticus*) on production the following season. *S. Afr. J. Anim. Sci.* 32, 226-230
- Brand, Z., Brand, T.S. & Brown, C.R., 2003. The effect of dietary energy and protein levels on production in breeding female ostriches. *Br. Poult. Sci.* 44, 598-606
- Bronner, F. & Stein, W.D., 1992. Modulation of bone calcium-binding sites regulates plasma calcium: a hypothesis. *Calcif. Tissue Int.* 50, 483-489

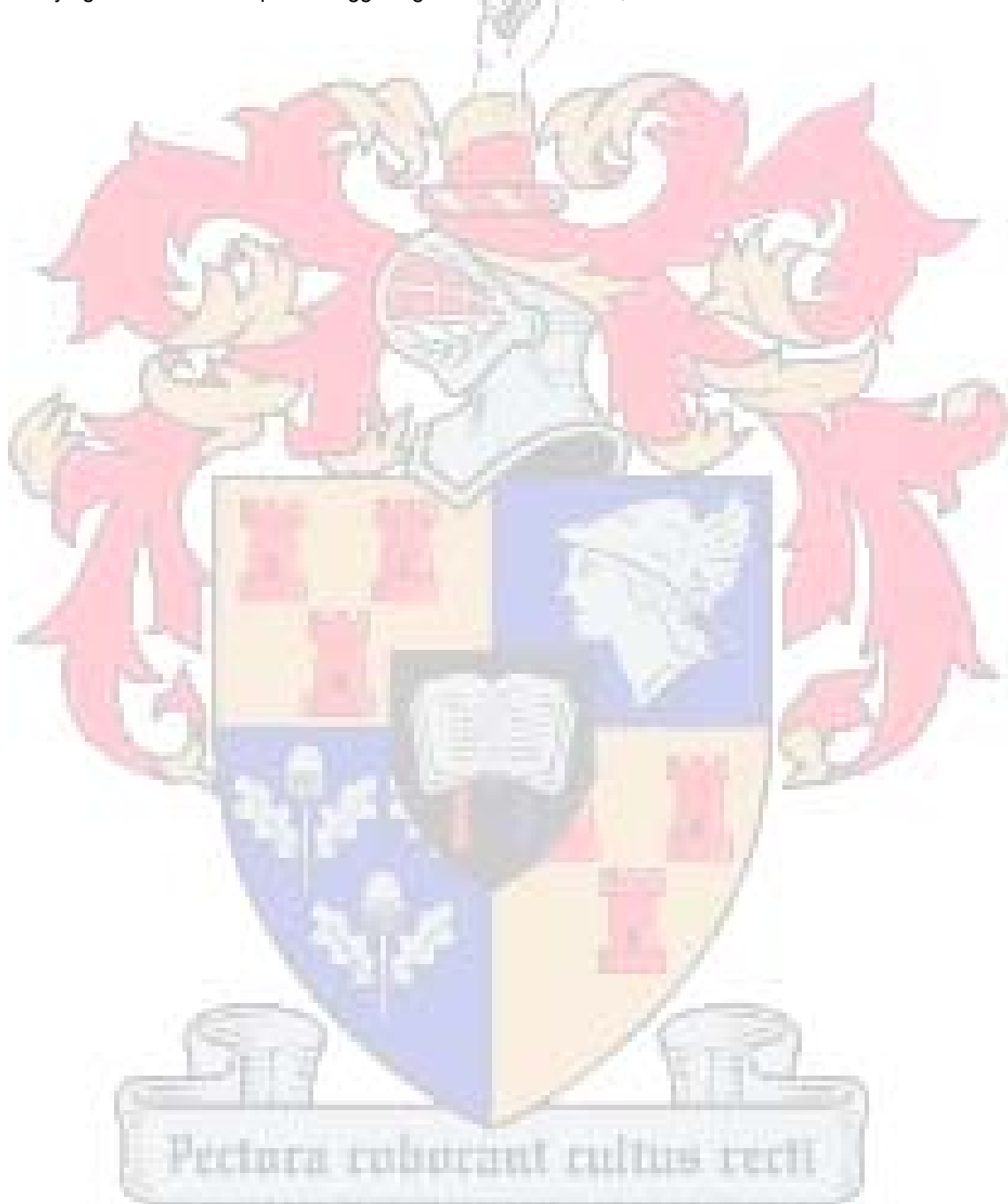
- Carey, J.B., Asher, R.K., Angel, J.F. & Lowder, L.S., 1991. The influence of methionine on egg composition. *Poult. Sci.* 70, Suppl. 1, Abstract, 151
- Caston, L. & Leeson, S., 1990. Research note: Dietary flax and egg composition. *Poult. Sci.* 69, 1617-1620
- Christians, J.K. & Williams, T.D., 2001. Interindividual variation in yolk mass and the rate of growth of ovarian follicles in the zebra finch (*Taeniopygia guttata*). *J. Comp. Physiol. B.* 171, 255-261
- Cilliers, S.C., Hayes, J.P., Chwalibog, A., Du Preez, J.J. & Sales, J., 1998. Determination of energy, protein and amino acid requirements for maintenance and growth in ostriches. *Anim. Feed Sci. Tech.* 72, 283-292
- Cilliers, S.C. & Van Schalkwyk, S.J., 1994. Volstruisproduksie (Ostrich production). Technical booklet. Little Karoo Agricultural Development Center, Oudtshoorn Experimental farm, P.O. Box 313, Oudtshoorn, 6620, South Africa
- Clunies, M., Parks, D. & Leeson, S., 1992. Calcium and phosphorus metabolism and eggshell formation of hens fed different amounts of calcium. *Poult. Sci.* 71, 482-489
- Di Meo, C., Stanco, G., Cutrignelli, M.I., Castaldo, S. & Nizza, A., 2003. Physical and chemical quality of ostrich eggs during the laying season. *Br. Poult. Sci.* 44, 386-390
- Du Preez, J.J., 1991. Ostrich nutrition and management. In: *Recent Advances in Animal Nutrition in Australia*. Ed. Farrell, D.J., University of New England, Armidale, Australia. pp. 278-291
- Folch, J., Lees, M. & Stanley, G.H., 1957. A simple method for the isolation and purification of total lipids from animal tissues. *J. Bio. Chem.* 226, 497-509
- Horwitz, W., 2002. *Official methods of analysis of AOAC international*. 17th edition, AOAC International, Maryland, USA
- Hussein, S.M., Harms, R.H. & Janky, D.M., 1993. Effect of age on the yolk to albumen ratio in chicken eggs. *Poult. Sci.* 72, 594-597
- Kritzinger, W.J., Brand, T.S., Hoffman, L.C. & Mellett, F.D., 2009. A description of body composition change in ostriches (*Struthio camelus*) under optimal feeding conditions. South Africa Society of Animal Science's 43rd Congress, 28-30 July 2009, Bergville, South Africa
- Lambrechts, H., 2006. Volstruishandleiding. Department of Agriculture: Western Cape & South African Ostrich Business Chamber. pp. 106-131
- Lin, C.Y., Friars, G.W. & Moran, E.T., 1980. Genetic and environmental aspects of obesity in broilers. *World's Poult. Sci. J.* 36, 103-111
- McDonald, P., Edwards, R.A., Greenhalgh, J.F.D. & Morgan, C.A., 2002. *Animal nutrition*. 6th edition. Prentice Hall, Harlow, England. pp. 286
- Novak, C., Yakout, H. & Scheideler, S., 2004. The combined effects of dietary lysine and total sulfur amino acid level on egg production parameters and egg components in Dekalb Delta laying hens. *Poult. Sci.* 83, 977-984
- Noble, R.C., Speake, B.K., McCartney, R., Foggin, C.M. & Deeming, D.C., 1996. Yolk lipids and their fatty acids in the wild and captive ostrich (*Struthio camelus*). *Comp. Biochem. Physiol.* 113B, 753-756
- Packard, M.J. & Packard, G.C., 1984. Comparative aspects of calcium metabolism in embryonic reptiles and birds. In: *Respiration and metabolism of embryonic vertebrates*. Ed: Seymour, R.S. Junk, Dordrecht. pp. 155-179

- Phenomenex, 2003. EZ:faast (easy fast) amino acid sample testing kit, User guide, Phenomenex, 411 Madrid Avenue, Torrance, CA 90501-1430, USA
- Phetteplace, H.W. & Watkins, B.A., 1989. Effects of various n-3 lipid sources of fatty acid composition in chicken tissues. *J. Food Compos. Anal.* 2, 104-117
- Pond, W.G., Church, D.C., Pond, K.R. & Schoknecht, P.A., 2005. Basic animal nutrition and feeding. 5th edition. John Wiley & Sons, Inc., pp.100
- Prochaska, J.F., Carey, J.B. & Shafer, D.J., 1996. The effect of L-Lysine intake on egg component yield and composition in laying hens. *Poult. Sci.* 75, 1268-1277
- Shafer, D.J., Carey, J.B. & Prochaska, J.F., 1996. Effects of dietary methionine intake on egg component yield and composition. *Poult. Sci.* 75, 1080-1085
- Shafer, D.J., Carey, J.B., Prochaska, J.F. & Sams, A.R., 1998. Dietary methionine intake effects on egg component yield, composition, functionality, and texture profile analysis. *Poult. Sci.* 77, 1056-1062
- Simkiss, K., 1991. Fluxes during embryogenesis. In: *Egg incubation: its effects on embryonic development in birds and reptiles*. Ed: Deeming, D.C. & Ferguson, M.W.J., Cambridge University Press, Cambridge, UK. pp.47-52
- Sooncharanying, S., & Edwards, H.M., 1989. Modelling the relationships of egg weight, specific gravity, shell calcium and shell thickness. *Br. Poult. Sci.* 30, 623-631
- Suk, Y.O. & Park, C., 2001. Effect of breed and age of hens on the yolk to albumen ratio in two different genetic stocks. *Poult. Sci.* 80, 855-858
- Superchi, P., Sussi, C., Sabbioni, A., & Beretti, V., 2002. Italian ostrich (*Struthio camelus*) eggs: Physical characteristics and chemical composition. *Ann. Fac. Medis. Vet. Di Parma.* 22, 155-162
- Sussi, C., Superchi, P., Sabbioni, A., Zambini, E.M., Beretti, V. & Zanon, A., 2003. Relationship between nutrition and reproductive efficiency in ostrich (*Struthio camelus*): yolk fatty acid content and fertility. *Ann. Fac. Medic. Vet. Di Parma.* 23, 253-260
- Swart, D., Siebrits, F.K. & Hayes, J.P., 1993. Utilization of metabolizable energy by ostrich (*Struthio camelus*) chicks at two different concentrations of dietary energy and crude fibre originating from lucerne. *S. Afr. J. Anim. Sci.* 23, 136-141
- Tichelaar, H.Y., Smuts, C.M., van Stuijvenberg, M.E., Faber, M. & Benade, A.J.S., 1998. The fatty acid status of rural school children with helminth infections. *Asia Pacific J. Clin. Nutr.* 7(2), 196-197
- Tuan, R.S., Ono, T., Akins, R.E. & Koide, M., 1991. Experimental studies on cultured, shell-less chick embryos: calcium transport, skeletal development and cardiovascular functions. In: *Egg incubation: its effects on embryonic development in birds and reptiles*. Ed: Deeming, D.C. & Ferguson, M.W.J., Cambridge University Press, Cambridge, UK. pp. 419-433
- Van Elswyk, M.E., 1997. Nutritional and physiological effects of flaxseed in diets for laying fowl. *World's Poult. Sci. J.* 53, 253-264
- Van Milgen, J., Noblet, J & Dubois, S., 2001. Energetic efficiency of starch, protein and lipid utilization in growing pigs. *J. Nutr.* 131, 1309-1318
- Van Soest, P.J., 1967. Development of a comprehensive system of feed analyses and its application to forages. *J. Anim. Sci.* 26, 119-128

Wang, Y.W., Cherian, G., Sunwoo, H.H. & Sim, J.S., 2000. Dietary polyunsaturated fatty acids significantly affect laying hen lymphocyte proliferation and immunoglobulin G concentration I serum and egg yolk. *Can. J. Anim. Sci.* 80, 597-604

Whitehead, C.C., Bowman, A.S. & Griffin, H.D., 1991. The effects of dietary fat and bird age on the weights of eggs and egg components in the laying hen. *Br. Poult. Sci.* 32, 565-574

Whitehead, C.C., Bowman, A.S. & Griffin, H.D., 1993. Regulation of plasma oestrogen by dietary fats in the laying hen: Relationships with egg weight. *Br. Poult. Sci.* 34, 999-1010



Chapter 5

Effect of dietary energy level on the feed intake and production of breeding ostriches

Abstract

Elucidating the factors affecting feed intake are important in order to quantify the nutrient requirements of breeding ostriches. Consequently, the average feed intake of breeding ostriches, together with production records, was calculated over one breeding season to determine if dietary energy affects feed intake. Six rations varying in ME content (8.0, 8.7, 9.4, 10.1, 10.8 and 11.5 MJ ME/kg feed) were provided *ad libitum* to both males and females. Records taken include total egg and chick production, infertile and dead-in-shell egg production and the change in mass of birds. Average feed intake (kg/bird/day) was not affected ($P>0.05$) at any dietary energy level ($3.7\pm 0.2\text{kg}$), nor was total egg (45.6 ± 5.8) (eggs/female/season) and chick production (21.3 ± 4.5), infertile (11.6 ± 3.6) and dead-in-shell egg production (7.5 ± 1.8), and the change in mass of female birds ($3.1\pm 3.4\text{kg}$). The mass of male birds increased significantly throughout the season ($P<0.05$). Ostrich birds are not able to regulate their feed intake at any dietary energy level as used in this study. The present research provides guidelines for the determination of the maximum feed intake and nutrient requirements of breeding ostriches.

Keywords: ostriches, nutrition, energy, feed intake, egg production, chick production

Introduction

It is currently not common practice to use the feeding strategies of poultry breeders for breeding ostriches. Gaining scientific information pertaining to the nutrient requirements of breeding ostriches are much needed in order to feed breeding ostriches to optimise production levels.

Feed intake of animals is regulated in a dialogue between the animal and the diet. This dialogue in turn is influenced by many factors (Ranft & Hennig, 1991). It is a well-known fact that poultry are able to control their feed intake at different dietary energy levels. Harms (1964) stated that the hen eats to meet the energy requirement, and that a sudden change in the dietary energy level will result in a change in feed intake to compensate for energy differences. It is uncertain whether the same is true for breeding ostriches. Determining how dietary energy affects feed intake is essential in determining if a ration will meet the requirements of the birds. Brand *et al.* (2004) and Brand *et al.* (2000) proved that slaughter ostriches are able to regulate their feed intake at various dietary energy levels. The investigation as to whether dietary energy interferes with the feed intake of ostrich birds will provide valuable guidelines for the determination of the nutrient requirement and maximum feed intake of breeding ostriches.

Material and Methods

Ninety pairs of breeding ostriches were divided into six groups, consisting of 15 breeding pairs per group. Six diets varying in ME content (8.0, 8.7, 9.4, 10.1, 10.8 and 11.5 MJ ME/kg feed) were provided *ad libitum* to both males and females. Protein and lysine were held constant at 12% and 0.58% respectively. The trial was conducted in Oudtshoorn (South Africa) during the 2008-2009 breeding season. The annual breeding season in South Africa starts in June and ends in January the following year. Table 5.1 lists the the raw materials and formulated nutrient composition and Table 5.2 the analyzed nutrient composition of each diet. Breeding pairs were kept in a 1:1 ratio in single breeding camps. Rations were given in the morning three times a week, and eggs were collected daily. The age of the birds used in the trial varied between 2 and 10 years.

Table 5.1 Ingredient and nutrient composition of the experimental diets with increasing ME content provided to ostrich birds during one season

Ingredients (kg/ton feed)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Energy level (MJ ME/kg feed)	8.0	8.7	9.4	10.1	10.8	11.5
Oats hulls	619	495	371	248	124	0.00
Maize	0.00	107	214	322	429	536
Alfalfa meal	0.00	35	69	104	138	173
Canola meal	242	215	188	162	135	108
Flaxseed	0.0	10	20	30	40	50
Limestone	45	44	43	42	41	40
Dicalciumphosphate	28	27	27	26	26	25
Molasses	50	50	50	50	50	50
Salt	10	10	10	10	10	10
Vitamin&mineral premix	5.00	5.00	5.00	5.00	5.00	5.00
Synthetic lysine	0.30	0.30	0.30	0.30	0.30	0.30
Nutrients						
ME (MJ ME/kg feed)	8.00	8.70	9.40	10.1	10.8	11.5
Crude protein (%)	12.0	12.0	12.0	12.0	12.0	12.0
Lysine (%)	0.60	0.60	0.60	0.60	0.60	0.60
Methionine&Cysteine (%)	0.46	0.50	0.50	0.50	0.50	0.47
Threonine (%)	0.45	0.50	0.50	0.50	0.50	0.45
Arginine (%)	0.59	0.60	0.60	0.60	0.60	0.63
Tryptophan (%)	0.15	0.10	0.10	0.10	0.10	0.13
Fat (%)	1.80	2.40	2.90	3.50	4.00	4.60
Fatty acid C18:2 (%)	0.00	0.30	0.60	0.90	1.20	1.50
Fiber (%)	20.7	18.0	15.2	12.5	9.70	7.00
Calcium (%)	2.60	2.60	2.60	2.50	2.50	2.50
Phosphorus (%)	0.60	0.60	0.60	0.60	0.60	0.60

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Table 5.2 Analyzed nutrient composition of the six experimental diets varying in ME content fed to breeding ostriches

Nutrient composition	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
ME (MJ ME/kg feed)	8.00	8.70	9.40	10.1	10.8	11.5
Crude protein (%)	12.7	12.8	12.9	12.8	12.8	13.2
Dry Material (%)	91.7	91.6	91.4	91.2	90.3	90.6
Ash (%)	12.4	12.0	12.0	11.9	11.5	12.2
Fat (%)	2.37	2.87	3.35	3.17	3.81	3.76
Crude fiber (%)	21.7	19.7	17.7	18.1	15.2	12.7

The average feed intake/bird/day was calculated as follows. The feed given to each camp was weighed each month and feed not eaten was weighed back at the end of the season. This represents the amount eaten for the camp for the whole season. The value was divided by the number of breeding days (210) and 2, since one female and one male were in the camp. The assumption was therefore made that the male and female in each camp would consume the same quantity of feed. Records were kept of total egg and chick production, dead-in-shell, and infertile egg production. The live mass of the birds were measured at the onset and end of the season to calculate the change in mass over the season. Statistical analysis was performed on the data, using Statgraphics (2005) for one-way ANOVA. To analyze the effect of age on the data, an ANACOVA was done using Statistica (2009). Diet was used as categorical predictor and age as the covariate.

Results and Discussion

Production results of breeding ostriches provided with diets with an increasing ME content are provided in Table 5.3. Average feed intake/bird/day (kg) amongst the different diets did not differ ($P>0.05$), with a mean feed intake value per bird of 3.7 ± 0.2 kg. Average feed intake was fairly constant and was therefore not suppressed at any dietary energy level. The result of the present study was not anticipated and is in contrast with the findings of Brand *et al.* (2004) and Brand *et al.* (2000) for slaughter ostriches. Several factors may have influenced the results obtained. Previous studies revealed that an ME intake of 22 MJ ME per bird per day is sufficient to maintain the energy requirement of female birds (Brand, 2008). The minimum average feed intake per day during the current study was 29.6 MJ ME/day. The increase in live mass of the birds (8.5 ± 1.07 kg; $P<0.05$) also indicates that the birds may have over-consumed energy on the diets with the higher energy values. This principle was also described by Brand & Gous (2006). The study also revealed that the age of the female birds had an influence on feed intake ($P<0.05$). Older female birds therefore tend to consume more feed on a daily basis and can possibly be ascribed to higher maintenance and egg production costs. It is of interest to note that the age of the males did not contribute to the observed variation among the male birds ($P>0.05$).

Table 5.3 Average feed intake and production records of ostrich birds fed diets varying in ME content

Energy level (MJ ME/kg feed)	8.0	8.7	9.4	10.1	10.8	11.5	
Crude protein (%)	12.0	12.0	12.0	12.0	12.0	12.0	
Lysine levels (%)	0.58	0.58	0.58	0.58	0.58	0.58	se ²
Average feed intake (kg/bird/day)	3.70 ^a	3.80 ^a	3.70 ^a	3.90 ^a	3.70 ^a	3.60 ^a	0.2
Egg production (eggs/female/season) (n ¹ =90)	47.2 ^a	43.9 ^a	48.3 ^a	57.1 ^a	33.6 ^a	43.6 ^a	5.8
Chick production (chicks/female/season)	20.0 ^a	18.3 ^a	18.5 ^a	32.6 ^a	16.5 ^a	21.6 ^a	4.5
Dead-in-shell eggs (eggs/female/season)	7.20 ^a	7.70 ^a	7.20 ^a	11.1 ^a	5.10 ^a	6.90 ^a	1.8
Infertile eggs (eggs/female/season)	13.7 ^a	13.9 ^a	16.7 ^a	7.70 ^a	7.80 ^a	9.70 ^a	3.6
Males' start mass (kg)	117.6 ^a	125.1 ^a	121.3 ^a	119.7 ^a	119.5 ^a	117.9 ^a	3.3
Males' end mass (kg)	122.9 ^a	127.9 ^a	126.4 ^a	130.5 ^a	130.8 ^a	133.5 ^a	4.0
Females' start mass (kg)	118.5 ^a	114.9 ^a	111.1 ^a	113.1 ^a	116.8 ^a	118.5 ^a	3.3
Females' end mass (kg)	116.4 ^a	116.5 ^a	114.3 ^a	111.3 ^a	117.7 ^a	128.5 ^a	4.9
Males' mass change (kg)	-2.10 ^a	1.60 ^a	3.20 ^a	4.90 ^a	0.90 ^a	10.0 ^a	3.4
Females' mass change (kg)	5.30 ^{ab}	2.80 ^a	5.10 ^a	10.8 ^{ab}	11.3 ^{ab}	15.6 ^b	2.4
Egg weight (g)	1488.1 ^a	1384.0 ^a	1367.1 ^a	1395.5 ^a	1374.1 ^a	1425.9 ^a	31.1

^{a,b} means in rows with different superscripts differ significantly (P<0.05)

¹n=number of females

²se=standard error

No significant differences ($P>0.05$) were observed for total eggs produced per female per season (45.6 ± 5.8), number of chicks hatched (21.3 ± 4.5), number of infertile eggs (11.6 ± 3.6), and for number of dead-in-shell egg



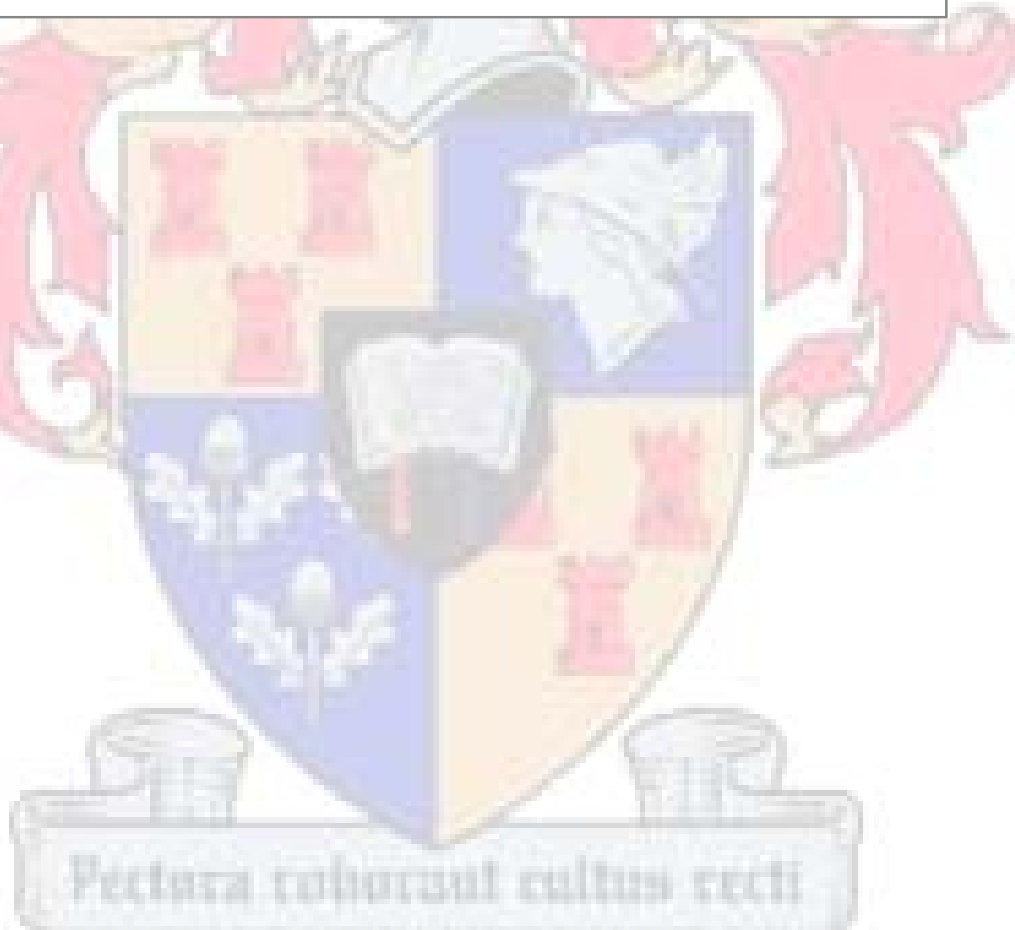
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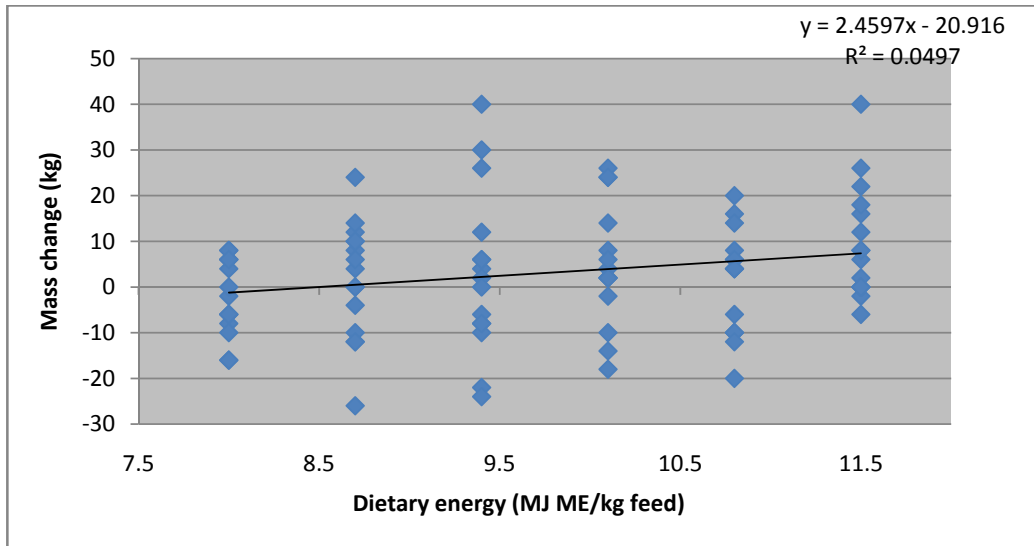
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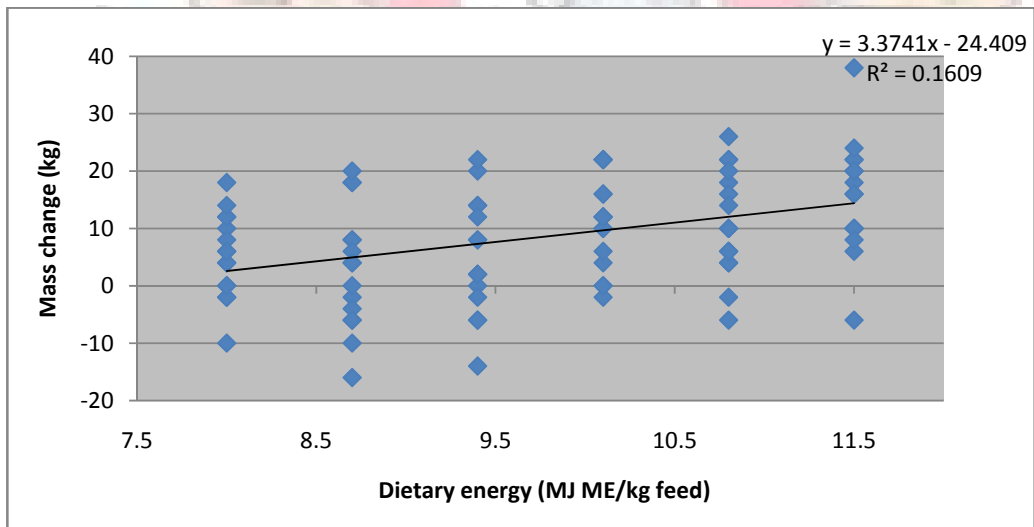
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Conclusion

No evidence exists from the present study that breeding ostriches were able to regulate their feed intake due to dietary energy level. This study also confirms that dietary energy has no significant influence on egg production, unless a lower daily ME allotment of 22 MJ ME/bird/day is given (Brand, 2008). Results from the present study are important for the determination of the nutrient requirements and maximum feed intake of breeding ostriches.

References

- Brand, T.S., 2008. Volstruisvoeding: 'n Wetenskaplike benadering. Sun Print, University of Stellenbosch, Stellenbosch. pp. 48
- Brand, T.S. & Gous, R.M., 2006. Feeding Ostriches. In: Feeding in domestic vertebrates: From structure to behaviour. Ed. Bels, V., CAB International, Wallingford, England. pp. 136-155
- Brand, T.S., Nell, C.J., & Van Schalkwyk, S.J., 2000. The effect of dietary energy and protein level on the production of growing ostriches. S. Afr. J. Anim. Sci. 30. Suppl. 1, 15-16
- Brand, Z., Brand, T.S. & Brown, C.R., 2003. The effect of dietary energy and protein levels on production in breeding female ostriches. Br. Poult. Sci. 44, 598-606
- Brand, T.S., Brundyn, L. & Brand, D.A., 2004. Wiskundige voedings-optimerings model vir volstruise – onlangse studies om die voedingsbehoefes van slagvoëls te beraam. Elsenburg Joernaal, 11-14
- Harms, R.H., 1964. Sudden feed changes and the laying hen. Feed Age. 14, 29-31
- Lin, C.Y., 1981. Relationship between increased body weight and fat deposition in broilers. World's Poult. Sci. J. 37, 106-110
- Lin, C.Y., Friars, G.W. & Moran, E.T., 1980. Genetic and environmental aspects of obesity in broilers. World's Poult. Sci. J. 36, 103-111
- Ranft, U. & Hennig, A., 1991. The regulation of feed intake and selection with special reference to poultry. Abstract. Arch. Für Tierernah. 41, 563-581
- Van Milgen, J., Noblet, J & Dubois, S., 2001. Energetic efficiency of starch, protein and lipid utilization in growing pigs. J. Nutr. 131, 1309-1318



Chapter 6

Growth and development of the reproductive organs of female breeding ostriches

Abstract

A study was conducted to determine the growth rate of the reproductive organs of breeding female ostriches, which may be used in a prediction model for estimating the nutrient requirements of ostrich breeding birds. Forty breeding female ostriches were sampled over an eight week period (five per week) starting at the onset of the breeding season. The ovary and oviducts were collected and weighed at each slaughter interval. No significant trend in the weight of the oviduct of the ostriches could be observed over the 49 day period, this weight being highly correlated with the body weight of the ostrich; whereas the ovary weight tended to be correlated with the time after the onset of the breeding period, although the variation in weights both within and between weightings was very high. The variation in the weight of the ovary probably reflects differences in the laying pattern of individuals, and this lends itself to simulating the ovulatory cycle and consequently gaining a better understanding of the process, which would in turn aid in determining the requirement for the nutrients responsible for the growth of the ova.

Keywords: ostriches, nutrition, ovaria, oviduct, liver, growth rate, protein, modelling, follicle

Introduction

The daily intake of nutrients to meet the requirements for maintenance, growth, and egg production are well defined for broilers and laying hens, but this is not the case with breeding ostriches. Whereas the protein and amino acid requirements for egg production in breeding ostriches as determined by du Preez (1991) were based on the weight of the egg and the bird, this approach has been shown to be less accurate than when the production requirements are based on the composition of the egg, and the maintenance requirements on the body protein content of the bird (Emmans & Fisher, 1986). Furthermore, Gous & Nonis (2009) have described the basis for calculating the nutrient requirements for egg production, these being based on the pattern of laying, which is in turn based on the internal cycle length of the hen, and the weights of the yolk and albumen, which differ as the hen ages. The calculations by du Preez (1991) were based on the assumptions that the breeding ostrich will lay an egg every second day and eat 2 kg feed per day. A study by Olivier *et al.* (2009) revealed that female birds can consume up to 3.7 kg feed per day in an *ad libitum* situation. Under controlled conditions birds are fed only 2.5 kg feed/day (Brand & Gous, 2006). Each female produces between 40 and 47 eggs per season (Brand *et al.*, 2002).

When calculating the nutrient requirements of the bird during the period immediately prior to the laying of the first egg, it is necessary to account for the growth of the oviduct and ovary. Bowmaker & Gous (1989) studied the growth of the liver, ovary and oviduct of broiler breeder pullets to calculate the dietary concentration of the protein, lysine, methionine, and tryptophan necessary to meet the requirements of these birds for maintenance and growth between the ages of 20 and 30 weeks. Different treatments were used to study the rate of development of the oviduct and ovary over time, but growth was the same with all treatments. The Gompertz growth curve fitted the data good.

Breeding ostriches need adequate daily intakes of protein for the growth of the reproductive organs. It is possible that reproductive potential is dependent on the growth rate of these organs, although this theory is not supported by some literature (Williams, 2005). Lambrechts (2006) reported that the reproductive ability of the ostrich is dependent on nutrition, behavior, management, and physiological health. Roland *et al.* (1974) stated that the weight of the ovary and oviduct of laying hens is reduced when the dietary calcium supply is less than 0.5 g calcium/kg food, thus emphasizing the importance of calcium on the reproductive performance of the laying hen.

In this study, the growth rate of the reproductive organs of the breeding female ostrich was investigated in order to gather data for the development of a model of the nutrient requirements of breeding ostriches (Gous & Brand, 2008).

Material and Methods

Forty female breeding ostriches were slaughtered over a period of eight weeks at a rate of five per week. The first group was slaughtered on the day of onset of the annual breeding season, when males are placed with the females. The ages of the birds varied between four and twelve years. The ovary and oviduct was removed from each bird and weighed. The vagina of each oviduct was removed since it is believed that this part of the oviduct would not vary in weight between the reproductive and non-reproductive states. The ovary, oviduct, and liver were analyzed for crude protein and crude fat. All crude protein and crude fat analysis was undertaken according to by the method used by Horwitz (2002). Crude protein was analyzed on a LECO FP-428 model, while crude fat analysis was conducted on a Tecator Soxtec System HT 1043 extraction unit. An ANOVA was performed on the data using the software program Statgraphics (2005), and simple linear regressions were fitted using Genstat (2008).

Results and Discussion

The mean weights of the reproductive organs that were taken at weekly intervals from the start of the breeding season, are given in Table 6.1 and Table 6.2. The observations within and between each interval

were extremely variable making it impossible to fit Gompertz growth curves to the data, as had been accomplished with broiler breeders (Bowmaker & Gous, 1989).

For the oviduct, there was no relationship between the weight of the oviduct and the age of the bird or days after mating, but there was a highly significant correlation with body weight (regression coefficient = 18.65 ± 5.54 g/kg body weight, $P < 0.01$).

The weight of the ovary was not correlated with age or body weight, but correlated with days after mating (26.44 ± 11.64 g/d, $P < 0.05$). The rate at which the ovary weight increases after the start of the mating period might be expected to show a curvilinear or exponential trend, reaching a peak and then flattening off, but data from this study did not support this.

Table 6.1 Mean and standard errors for the weight and chemical composition of the ovary of female breeding ostriches

Days after mating	Weight (g)	Moisture (%)	Ash (%)	Crude protein (g) ¹	Crude protein (%)	Fat (g) ¹	Fat (%)
0	513 ^a	72.4	5.1	73.0 ^a	49.8	90.4 ^a	39.7
7	1394	57.1	4.3	285.3	46.1	312.5	51.3
14	2030	64.0	3.8	291.6	42.0	435.7	46.3
21	775	68.6	5.2	106.9	42.9	144.1	44.9
28	2046	63.9	3.8	310.2	40.6	461.4	47.6
35	1744	61.7	4.0	267.0	41.1	378.2	45.9
42	1625	62.7	4.7	247.3	42.1	367.7	47.4
49	2399 ^a	58.5	3.7	338.8 ^a	34.3	559.0 ^a	54.4
se ²	1031.9			84.2		132.2	

^{a,b} means in columns with different superscripts differ significantly ($P < 0.05$)

¹ crude protein (g) and fat value (g) are on an as is basis

² se=standard error

The variation observed in these organs is probably due to the fact that egg production is highly variable in breeding female ostriches. It may be speculated that female birds with a high predicted breeding value for egg production, would have higher weights for the reproductive organs; while birds with a low predicted breeding value, would consequently have lower weights. The variation in ovary weight reflects differences in the number of developing ova, which would be expected to be highly variable in this species.



Table 6.2 Mean and standard errors for the weight and chemical composition of the oviduct of female breeding ostriches

Days after mating	Weight (g)	Moisture (%)	Ash (%)	Crude protein (g) ¹	Crude protein (%)	Fat (g) ¹	Fat (%)
0	516 ^a	84.7	6.6	71.2 ^a	76.1	12.5 ^a	18.0
7	932	82.3	5.3	111.9	78.1	25.0	13.6
14	694	81.1	4.7	124.4	76.9	24.1	16.4
21	484	81.4	5.0	68.5	77.6	12.5	15.3
28	813	79.3	4.6	134.5	77.2	19.0	13.6
35	853	80.4	4.6	127.5	74.8	26.5	16.9
42	842	82.4	5.1	130.9	85.0	10.3	6.6
49	868 ^a	78.7	4.4	133.0 ^a	70.2	35.1 ^a	20.8
se ²	384.4			31.8		5.9	

^{a,b} means in columns with different superscripts differ significantly ($P < 0.05$)

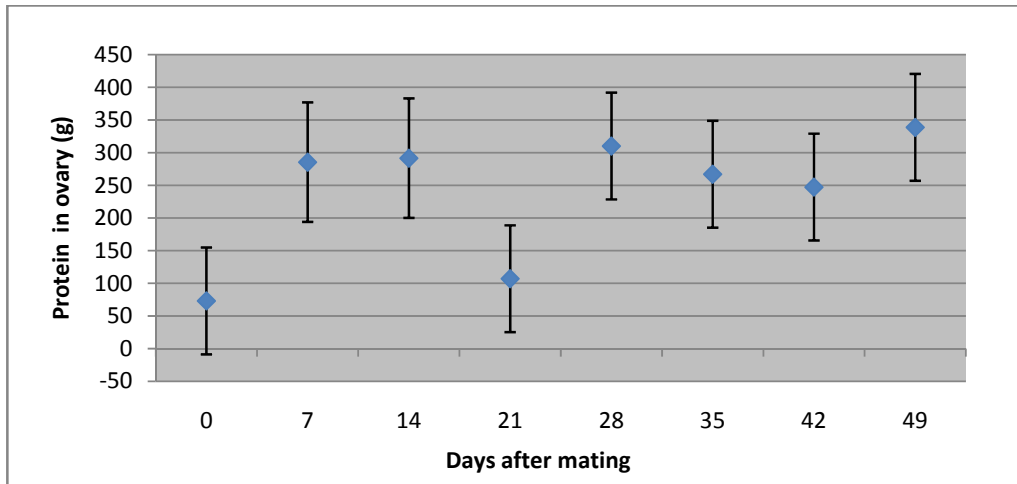
¹ crude protein (g) and fat value (g) are on an as is basis

² se=standard error

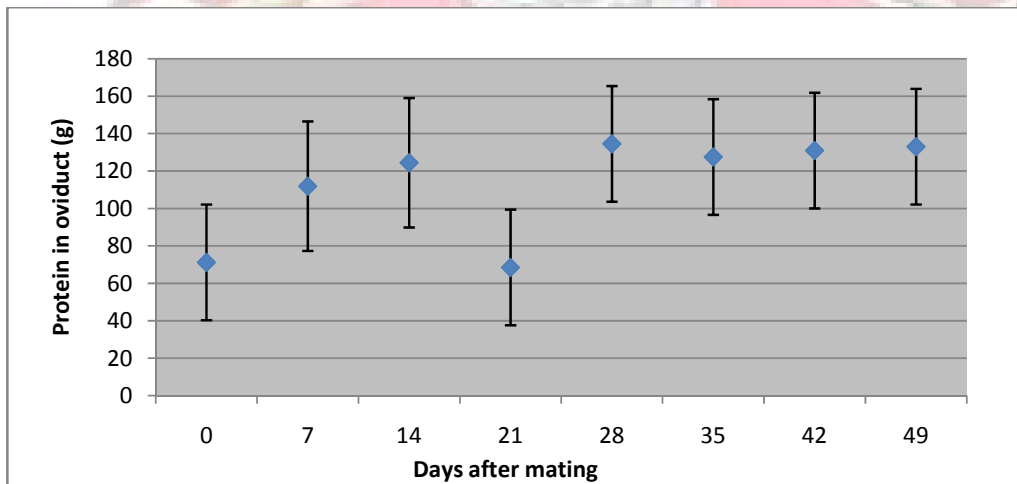
The oviduct weights of birds in an immature sexual state, obtained either before the onset of the first laying period or midway between successive breeding periods, would give a better indication of the extent to which the oviduct would need to grow to reach a sexually mature state. Similarly, the weight of the ovary prior to the development of ova would be a useful measure, to which the weights of the developing ova could be added to determine the nutrient requirements for the growth of these ova. To date, the ovulatory cycle of the female ostrich has not been studied mathematically, and this would be a useful exercise in determining the nutrient requirements for egg production in this species.

No significant difference was observed between day 0 and 49 ($P > 0.05$) for crude protein and fat content on an as is basis. The crude protein percentage of each ovary varied widely, with range of 32.6% - 79.2%. A finding from this observation is that the smaller ovaries contain more protein than the heavier ovaries. The crude protein content of the oviduct varied less, ranging from 57.8% - 94.3%.



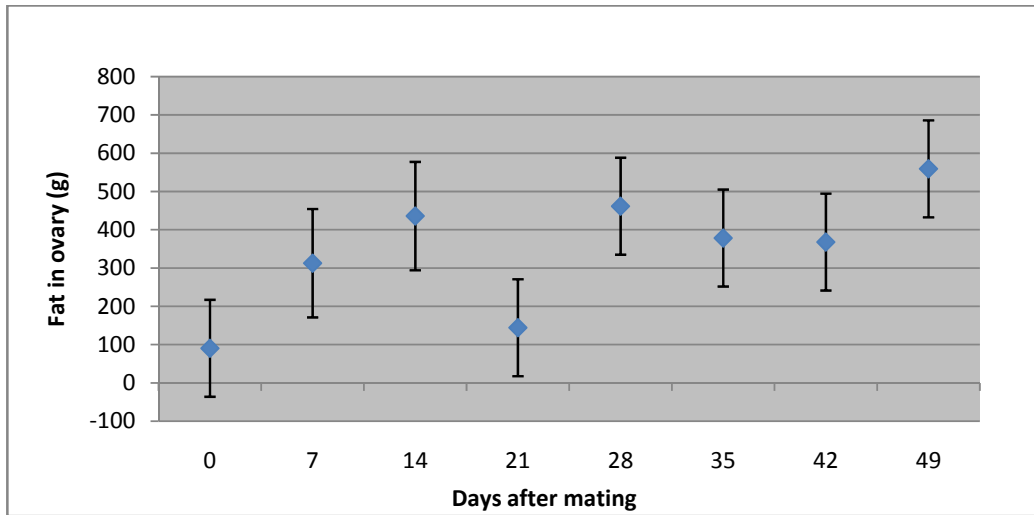


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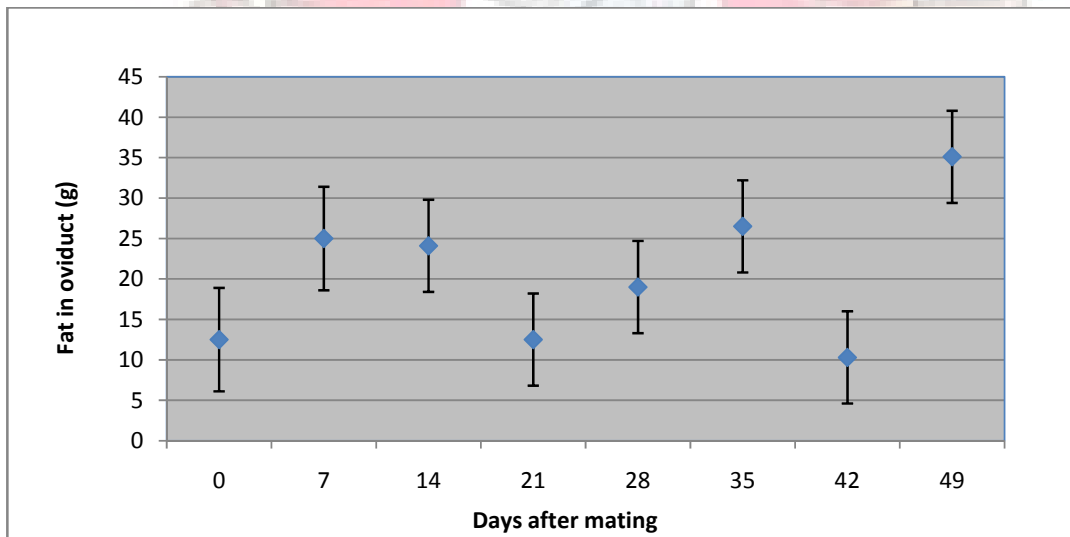


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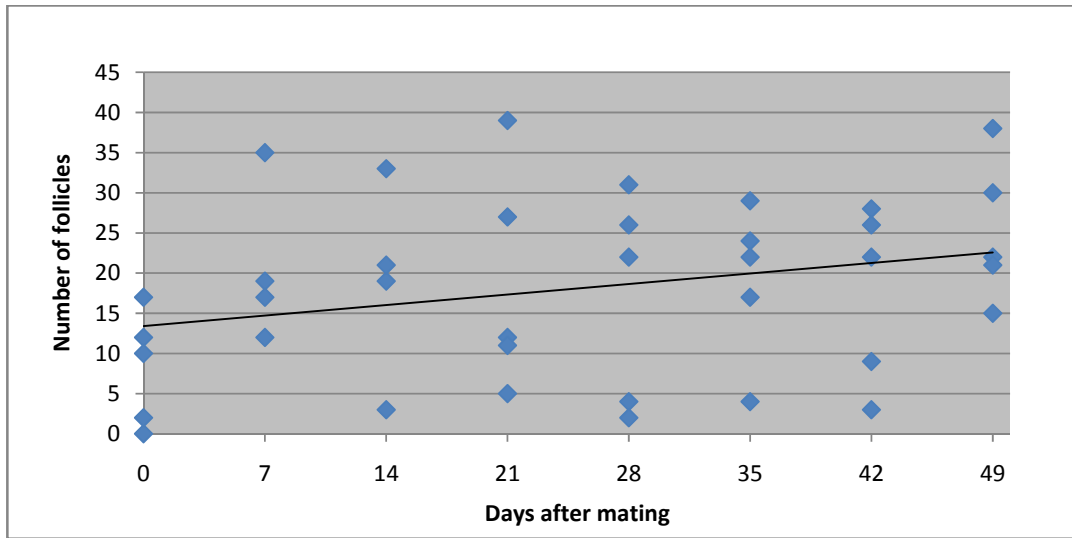


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Table 6.3 Mean and standard errors for the weight and chemical composition of the liver of female breeding ostriches

Days after mating	Weight (g)	Moisture (%)	Ash (%)	Crude protein (g) ¹	Crude protein (%)	Fat (g) ¹	Fat (%)
0	1918.0 ^a	71.3	4.1	348.3 ^a	63.6	60.9 ^a	11.2
7	1541.6	70.2	5.0	307.2	64.3	117.0	24.2
14	1861.3	70.6	4.5	321.7	59.0	101.7	19.0
21	1452.0	72.0	5.3	298.2	72.1	62.8	14.9
28	1819.2	70.6	4.8	336.5	61.7	87.8	15.1
35	1646.0	72.6	5.7	317.0	69.9	99.7	21.4
42	1570.6	73.4	4.9	305.4	73.0	59.6	14.0
49	1491.5 ^b	71.2	6.3	298.5 ^a	69.5	78.1 ^a	18.3
Se ²	111.4			19.5		14.3	

^{a,b} means in columns with different superscripts differ significantly (P<0.05)

¹crude protein (g) and fat value (g) are on an as is basis

²se=standard error

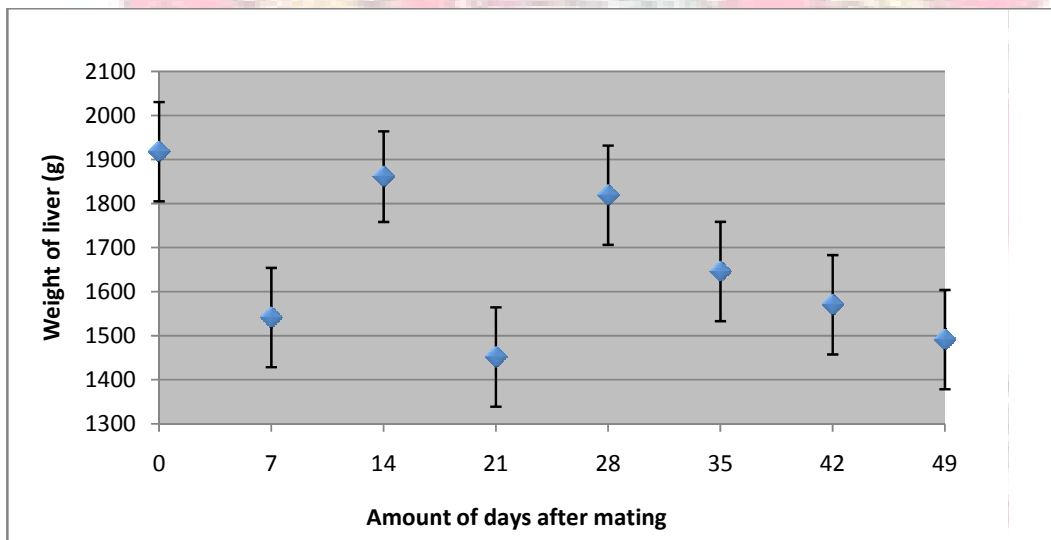
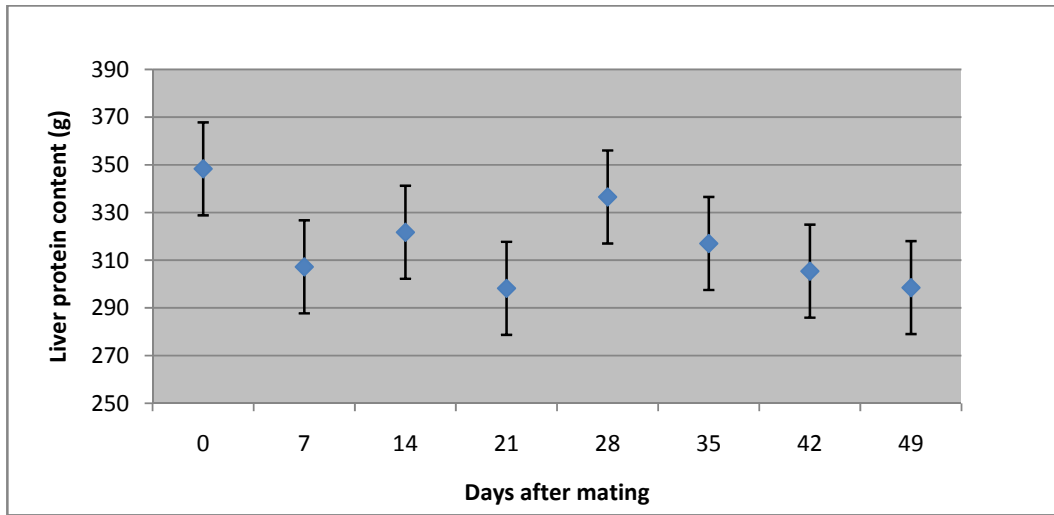


Figure 6 Liver weights of female breeding ostriches





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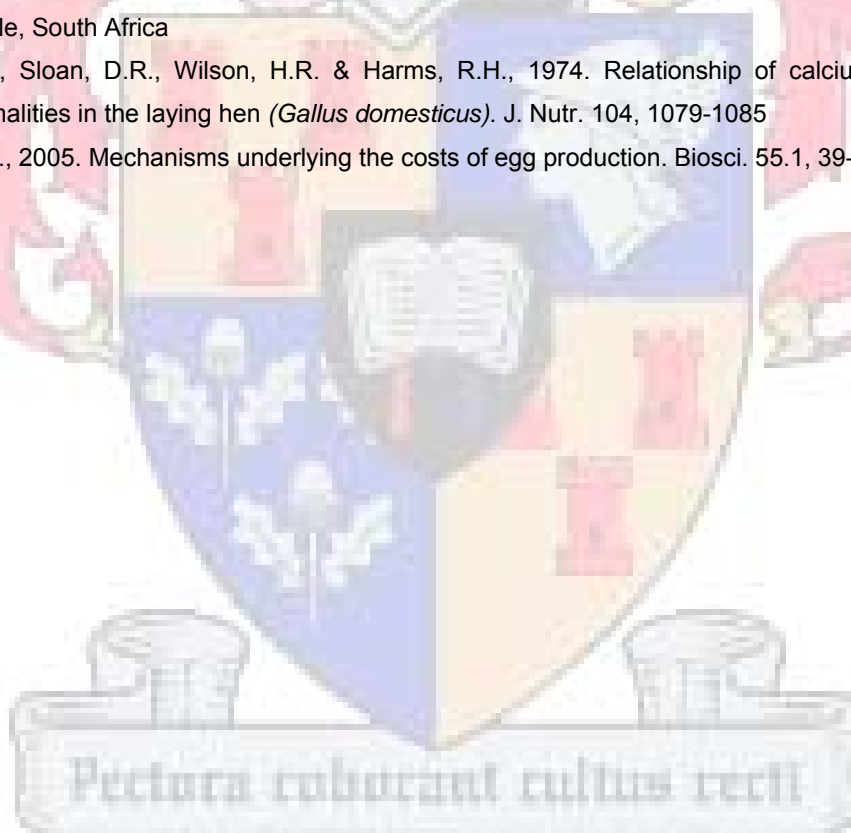
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- Brand, Z., Brand, T.S. & Brown, C.R., 2002. The effect of dietary and protein levels during a breeding season of ostriches (*Struthio camelus domesticus*) on production the following season. S. Afr. J. Anim. Sci. 32, 226-230
- Du Preez, J.J., 1991. Ostrich nutrition and management. In: Recent Advances in Animal Nutrition in Australia. Ed. Farrell, D.J., University of New England, Armidale, Australia. pp. 278-291
- Emmans, G.C. & Fisher, C. 1986. Problems in nutritional theory, Poultry Science Symposium No.19. In: Nutrient requirements of poultry and nutritional research. Ed. Fisher, C. & Boorman, K.N., Butterworths, London. pp. 9-39
- GenStat 2008. GenStat 11th Edition, VSN International. Hemel Hempstead U.K.
- Gous, R.M. & Brand, T.S., 2008. Developing simulation models for food intake and growth of ostriches, 4th Int. Rat. Sci. Sym, 1-4 July 2008, Brisbane, Australia
- Gous, R.M. & Nonis, M.A., 2009. Modelling egg production and nutrient responses in broiler breeder hens. J. Ag. Sci. in Press.
- Horwitz, W., 2002. Official methods of analysis of AOAC International. 17th edition, AOAC International, Maryland, USA
- Lambrechts, H., 2006. Volstruushandleiding. Department of Agriculture: Western Cape & South African Ostrich Business Chamber. pp. 106-131
- Olivier, T.R., Brand, T.S. & Brand, Z., 2009. Production and the effect of dietary energy level on the feed intake of breeding ostriches. South Africa Society of Animal Science's 43rd Congress, 28-30 July 2009, Bergville, South Africa
- Roland, D.A., Sloan, D.R., Wilson, H.R. & Harms, R.H., 1974. Relationship of calcium to reproductive abnormalities in the laying hen (*Gallus domesticus*). J. Nutr. 104, 1079-1085
- Williams, T.D., 2005. Mechanisms underlying the costs of egg production. Biosci. 55.1, 39-48



Chapter 7

Egg laying patterns of the female breeding ostrich

Abstract

In three experiments, the egg laying pattern as well as the frequency of egg laying of breeding female ostriches was studied. In Experiment 1, five diets varying in dietary protein (7.5%, 9.1%, 10.8%, 12.3% and 14%) were given to females at a rate of 2.5 kg/bird/day. Experiments 2 and 3 consisted of the following dietary ME treatments respectively: 7.5, 8.0, 8.5, 9.0, 9.5 and 10.0 MJ ME/kg feed and 8.0, 8.7, 9.4, 10.1, 10.8, 11.5 MJ ME/kg feed. Feed intake for Experiment 2 was 3.4 kg/bird/day; and for experiment 3 *ad libitum*. None of the dietary treatments affected the mean frequency of lay (eggs/female/month) and mean weekly egg laying patterns (eggs/week) of female ostrich birds significantly ($P>0.05$). Means and standard errors of frequency of egg lay for Experiment 1, 2 and 3 were 5.0 ± 0.2 , 5.6 ± 0.9 , 6.2 ± 0.8 eggs/month and 1.1 ± 0.2 , 1.4 ± 0.2 , 1.6 ± 0.2 respectively for the weekly egg laying pattern. Egg production in female breeding ostriches was highly erratic and not influenced by different dietary protein and energy levels at these feed intake levels; nor does dietary protein and energy affect the egg laying patterns of ostrich birds, as shown in these studies.

Keywords: ostriches, nutrition, egg production, energy, protein

Introduction

The laying hen lays an egg every day during a period of sequential egg-laying which is normally called a clutch, which are normally separated from each other by a pause day (Zakaria *et al.*, 1984). The egg-laying characteristics of the laying fowl can be influenced by external factors like nutrition and the ambient temperature (Al-Saffar & Rose, 2002). Weber (2009) stated that an adequate supply of all nutrients is important to maximise the productivity of the laying hen. The cause of low egg production in broiler breeders is not well understood (Hocking *et al.*, 1987). Nutrition related factors like obesity can contribute to below average egg production in broiler breeders (Robinson & Wilson, 1996). It was indicated by Malden *et al.* (1979) that egg production were depressed when broilers breeders were too fat. A possible cause is that excess fat deposits can prevent eggs from deposited in the oviduct (Badley, 1997). Scott *et al.* (1969) conveyed that excess fat that is deposited in adipose tissue surrounding the reproductive organs will influence egg production. Therefore it is common practice to restrict the feed intake of broiler breeders. The rate of lay is subsequently raised

No information is available that proves whether nutrition affects the egg-laying pattern of breeding ostriches. The purpose of the investigation is to establish the egg laying patterns of the breeding ostrich at different nutritional levels.

Material and Methods

The study consists of three experiments. For Experiment 1, 100 female breeding ostriches were divided into five groups, consisting of twenty birds per group. Five different diets were given at 2.5 kg/bird/day to both males and females over two subsequent breeding seasons. Energy levels were held constant at 9.2 MJ ME/kg feed. For Experiment 2, ninety pairs of breeding ostriches were divided into six groups, consisting of 15 breeding pairs per group. Six diets varying in ME content (7.5, 8.0, 8.5, 9.0, 9.5 and 10.0 MJ ME/kg feed) were provided at a rate of 3.4 kg/bird/day. Dietary protein level was held constant at 12%. Experiment 3, ninety pairs of breeding ostriches were divided into six groups, consisting of 15 breeding pairs per group. Six diets varying in ME content (8.0, 8.7, 9.4, 10.1, 10.8 and 11.5 MJ ME/kg feed) were provided *ad libitum*. Tables 1 – 5 provides the nutrient and raw material content of each experiment.

All experiments were conducted in Oudtshoorn (South Africa) over one breeding season, except Experiment 1 which covered two breeding seasons. Breeding pairs were kept in a 1:1 ratio in a single breeding camp. The annual breeding season in South Africa starts in June and ends in January the following year. The same feed was given to both males and females. Statistical analysis was performed on the data, using Statgraphics (2005) for one-way ANOVA. To analyze the effect of age on the data, an ANACOVA was done using Statistica (2009). Diet was used as the categorical predictor and age as the covariate.

Table 7.1 Ingredient and nutrient content of the five experimental diets with increasing crude protein content provided to ostrich birds during two seasons (Experiment 1)

Ingredients (kg/ton feed)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Oat Bran	490	467	444	420	397
Maize	207	195	184	172	160
Wheat Bran	197	148	99	49	0
Lucerne	0	38	75	113	150
Soyabean oilcake meal	0	27	53	80	106
Sunflower oilcake meal	0	23	45	68	90
Limestone	60	58	56	54	52
Molasses	25	25	25	25	25
Monocalciumphosphate	12	12	12	12	12
Salt	4.00	4.00	4.00	4.00	4.00
Premix	2.50	2.50	2.50	2.50	2.50
Lysine	1.66	1.25	0.83	0.42	0.00
Threonine	0.78	0.00	0.70	0.67	0.63
Methionine	0.48	0.46	0.43	0.41	0.38
Nutrients					
Metabolisable energy (MJ ME/kg)	9.20	9.20	9.20	9.20	9.20
Crude protein (%)	7.50	9.10	10.8	12.3	14.0
Lysine (%)	0.29	0.36	0.44	0.51	0.58
Threonine (%)	0.23	0.29	0.34	0.40	0.45
Methionine+Cysteine (%)	0.21	0.27	0.32	0.38	0.43

Table 7.2 Ingredient and nutrient content of the experimental diets varying in ME content fed to breeding ostriches (Experiment 2)

Composition (kg/ton feed)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Energy level (MJ ME/kg feed)	7.5	8.0	8.5	9.0	9.5	10.0
Oat Bran	670	536	402	268	134	0
Maize meal	0	110	220	330	440	550
Lucern hay	48.6	90.1	131.6	173	214.5	256
Soyabean oilcake	165	142.4	119.8	97.2	74.6	52
Flaxseed	0	10	20	30	40	50
Limestone	50	48.8	47.6	46.4	45.2	44
Dicalciumphosphate	30	26.9	23.9	20.8	17.8	14.7
Molasses	20	20	20	20	20	20
Salt	10	10	10	10	10	10
Mineral&Vitamin premix	2.50	2.50	2.50	2.50	2.50	2.50
Synthetic lysine	0.80	0.80	0.70	0.70	0.60	0.60
Synthetic methionine	1.90	1.60	1.20	0.90	0.50	0.20
Synthetic threonine	1.20	1.00	0.70	0.50	0.20	0.00
Nutrients						
ME (MJ ME/kg feed)	7.5	8.0	8.5	9.0	9.5	10.0
Crude protein (%)	12.0	12.0	12.0	12.0	12.0	12.0
Lysine (%)	0.58	0.58	0.58	0.58	0.58	0.58
Methionine-cysteine (%)	0.42	0.42	0.43	0.43	0.43	0.44
Threonine (%)	0.45	0.46	0.46	0.47	0.48	0.49
Arginine (%)	0.59	0.60	0.62	0.63	0.65	0.66
Tryptophane (%)	0.13	0.15	0.16	0.17	0.19	0.20
Isoleucine (%)	0.44	0.45	0.45	0.46	0.47	0.47
Fat (%)	1.10	1.90	2.70	3.50	4.20	5.00
Fatty acid C18:2 (%)	0.08	0.34	0.60	0.87	1.13	1.39
Fatty acid C18:3 (%)	0.02	0.21	0.41	0.61	0.80	1.00
Fiber (%)	20.7	18.4	16.1	13.8	11.4	9.10
Calcium (%)	2.70	2.70	2.60	2.60	2.50	2.40
Phosphorus (%)	0.60	0.60	0.60	0.60	0.50	0.50

Table 7.3 Analyzed nutrient composition of the six experimental diets varying in ME content fed to breeding ostriches (Experiment 2)

Nutrient composition	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
ME (MJ ME/kg feed)	8.06	5.25	8.20	7.27	8.13	9.13
Crude protein (%)	13.3	12.6	11.6	11.1	11.4	10.9
Dry Material (%)	92.0	92.1	91.5	91.0	90.7	90.6
Ash (%)	13.3	11.3	10.4	11.2	10.1	10.3
Fat (%)	2.10	2.50	3.20	3.90	4.30	4.90
Crude fiber (%)	20.6	18.3	16.3	15.5	13.3	8.90
Calcium (%)	3.00	3.00	3.20	3.10	2.80	2.60
Phosphorus (%)	0.50	0.70	0.70	0.60	0.50	0.50

Table 7.4 Ingredient and nutrient composition of the experimental diets with increasing ME content provided to ostrich birds during one season (Experiment 3)

Ingredients (kg/ton feed)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Energy level (MJ ME/kg feed)	8.0	8.7	9.4	10.1	10.8	11.5
Oats hulls	619	495	371	248	124	0.00
Maize	0.00	107	214	322	429	536
Alfalfa meal	0.00	35	69	104	138	173
Canola meal	242	215	188	162	135	108
Flaxseed	0.0	10	20	30	40	50
Limestone	45	44	43	42	41	40
Dicalciumphosphate	28	27	27	26	26	25
Molasses	50	50	50	50	50	50
Salt	10	10	10	10	10	10
Vitamin&mineral premix	5.00	5.00	5.00	5.00	5.00	5.00
Synthetic lysine	0.30	0.30	0.30	0.30	0.30	0.30
Nutrients						
ME (MJ ME/kg feed)	8.0	8.7	9.4	10.1	10.8	11.5
Crude protein (%)	12.0	12.0	12.0	12.0	12.0	12.0
Lysine (%)	0.60	0.60	0.60	0.60	0.60	0.60
Methionine&Cysteine (%)	0.46	0.50	0.50	0.50	0.50	0.47
Threonine (%)	0.45	0.50	0.50	0.50	0.50	0.45
Arginine (%)	0.59	0.60	0.60	0.60	0.60	0.63
Tryptophan (%)	0.15	0.10	0.10	0.10	0.10	0.13
Fat (%)	1.80	2.40	2.90	3.50	4.00	4.60
Fatty acid C18:2 (%)	0.00	0.30	0.60	0.90	1.20	1.50
Fiber (%)	20.7	18.0	15.2	12.5	9.70	7.00
Calcium (%)	2.60	2.60	2.60	2.50	2.50	2.50
Phosphorus (%)	0.60	0.60	0.60	0.60	0.60	0.60

Table 7.5 Analyzed nutrient composition of the six experimental diets varying in ME content fed to breeding ostriches (Experiment 3)

Nutrient composition	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
ME (MJ ME/kg feed)	8.00	8.70	9.40	10.1	10.8	11.5
Crude protein (%)	12.7	12.8	12.9	12.8	12.8	13.2
Dry Material (%)	91.7	91.6	91.4	91.2	90.3	90.6
Ash (%)	12.4	12.0	12.0	11.9	11.5	12.2
Fat (%)	2.37	2.87	3.35	3.17	3.81	3.76
Crude fiber (%)	21.7	19.7	17.7	18.1	15.2	12.7

Results and Discussion

Mean frequency of egg laying is recorded as eggs per female per month. No significant difference ($P>0.05$) was observed for any of the three experiments. A tendency ($P=0.06$) for a higher frequency of egg laying was noticed in experiment 1. The means and standard errors for experiments 1 - 3 were respectively 5.0 ± 0.2 , 5.6 ± 0.9 and 6.2 ± 0.8 . Tables 7.6 – 7.8 list the results of the egg laying frequencies. The weekly egg

pattern (eggs/week) for each month is displayed in Tables 7.9 – 7.11. Similarly no difference ($P>0.05$) was observed for any experiment for the mean weekly egg laying pattern. A tendency for more eggs laid per week ($P=0.06$) was noticed in Experiment 1. Analysis of covariance (ANACOVA) revealed that age had an influence ($P<0.05$) on the mean frequency of lay and on the mean weekly egg laying pattern for experiments 1 and 2. Ostriches therefore tend to lay more eggs on a weekly and monthly basis as they get older. Figures 1 – 4 shows the mean frequency of lay and the mean weekly egg laying pattern of the different age groups.

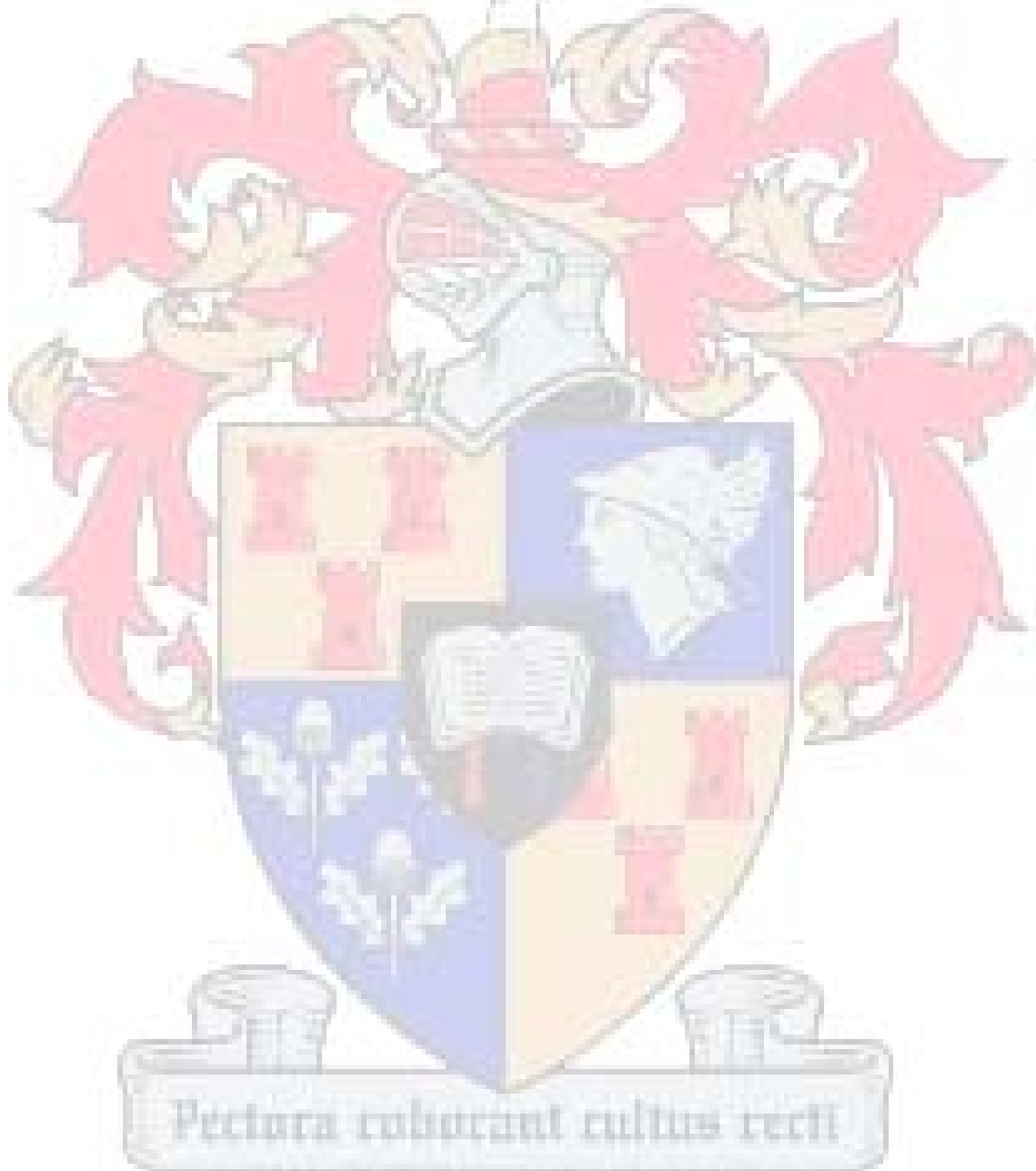


Table 7.6 Frequency of egg laying (eggs/female/month) for Experiment 1

Treatment (% CP)	May	June	July	August	September	October	November	December	January	Mean
7.5	0.05	2.6	5.7	6.2	5.7	5.7	5.5	3.5	2.0	4.6 ^a
9.1	0.1	4.6	7.8	7.7	7.3	6.2	5.6	5.9	2.4	5.9 ^a
10.8	0.2	5.0	7.6	7.1	8.0	5.4	5.1	3.8	1.7	5.4 ^a
12.3	0.1	2.8	6.3	6.5	6.4	4.9	5.2	3.0	1.4	4.6 ^a
14.0	0.0	2.2	6.4	6.2	7.2	4.9	4.1	3.3	1.4	4.4 ^a
Mean and se¹	0.1±0.04	3.4±0.3	6.7±0.4	6.7±0.4	6.9±0.4	5.4±0.3	5.1±0.3	3.9±0.3	1.8±0.2	5.0±0.2

means in columns with same superscript do not differ significantly (P>0.05)

¹se=standard error

Table 7.7 Frequency of egg laying (eggs/female/month) for Experiment 2

Treatment (MJ ME/kg feed)	May	June	July	August	September	October	November	December	January	Mean
7.5	0.0	1.2	4.9	5.8	4.5	6.7	5.5	6.4	5.8	5.1 ^a
8.0	0.0	1.1	3.0	6.0	4.4	5.5	5.1	5.3	4.8	4.4 ^a
8.5	0.1	1.7	4.9	8.0	8.9	7.7	7.5	8.5	6.5	6.7 ^a
9.0	0.1	0.9	2.4	5.8	6.4	7.3	6.7	6.1	6.9	5.3 ^a
9.5	0.0	1.5	4.1	8.1	9.0	8.3	6.1	8.1	5.8	6.2 ^a
10.0	0.1	3.0	4.1	5.8	7.3	5.8	6.7	7.1	6.6	5.9 ^a
Mean and se¹	0.1±0.1	1.4±0.9	4.0±1.3	6.6±1.5	6.8±1.4	6.9±1.4	6.3±1.4	6.9±1.3	6.1±1.3	5.6±0.9

means in columns with same superscript do not differ significantly (P>0.05)

¹se=standard error

Table 7.8 Frequency of egg laying (eggs/female/month) for Experiment 3

Treatment (MJ ME/kg feed)	May	June	July	August	September	October	November	December	Mean
8.0	0.4	2.8	7.8	8.6	9.8	7.6	8.4	1.8	6.4 ^a
8.7	0.3	1.3	7.8	8.7	8.9	9.1	7.1	0.7	6.1 ^a
9.4	0.0	1.6	6.7	7.5	10.6	10.5	9.3	2.1	6.6 ^a
10.1	0.0	3.7	9.9	10.4	10.2	10.2	9.9	2.8	7.8 ^a
10.8	0.0	1.5	5.5	5.3	6.20	6.3	7.2	1.5	4.6 ^a
11.5	0.3	2.1	4.6	8.2	10.6	8.3	8.0	1.5	6.0 ^a
Mean and se¹	0.2±0.2	2.2±1.0	7.0±1.5	8.10±1.3	9.40±1.2	8.70±1.3	8.3±1.3	1.7±0.4	6.2±0.8

means in columns with same superscript do not differ significantly (P>0.05)

¹se=standard error

Table 7.9 Weekly laying pattern (eggs/week) for Experiment 1

Treatment (% CP)	Week 1-4	Week 5-8	Week 9-12	Week 13-16	Week 17-20	Week 21-24	Week 25-28	Week 29-32	Mean
7.5	0.7	1.4	1.5	1.4	1.4	1.4±	0.9	0.5	1.1 ^a
9.1	1.1	1.9	1.9	1.8	1.5	1.4±	1.5	0.6	1.5 ^a
10.8	1.2	1.9	1.8	2.0	1.4	1.2±	0.9	0.4	1.4 ^a
12.3	0.7	1.6	1.6	1.6	1.2	1.3±	0.7	0.4	1.1 ^a
14.0	0.5	1.6	1.0	1.8	1.2	1.0±	0.8±	0.4	1.1 ^a
Mean and se¹	0.9±0.1	1.7±0.1	1.7±0.1	1.7±0.1	1.3±0.1	1.3±0.1	1.0±0.1	0.4±0.1	1.2±0.1

means in columns with same superscript do not differ significantly (P>0.05)

¹se=standard error

Table 7.10 Weekly laying pattern (eggs/week) for Experiment 2

Treatment (MJ ME/kg feed)	Week 1-4	Week 5-8	Week 9-12	Week 13-16	Week 17-20	Week 21-24	Week 25-28	Week 29-32	Mean
7.5	0.3	1.2	1.5	1.1	1.7	1.4	1.6	1.5	1.3 ^a
8.0	0.3	0.8	1.5	1.1	1.4	1.3	1.3	1.2	1.1 ^a
8.5	0.4	1.2	2.0	2.2	1.9	1.9	2.1	1.6	1.7 ^a
9.0	0.2	0.6	1.5	1.6	1.8	1.7	1.5	1.7	1.3 ^a
9.5	0.1	1.0	2.0	2.3	2.1	1.5	2.1	1.5	1.6 ^a
10.0	0.8	1.2	1.5	1.8	1.5	1.7	1.8	1.7	1.5 ^a
Mean and se¹	0.4±0.2	1.0±0.3	1.6±0.4	1.7±0.3	1.7±0.3	1.6±0.3	1.7±0.3	1.5±0.3	1.4±0.2

means in columns with same superscript do not differ significantly (P>0.05)

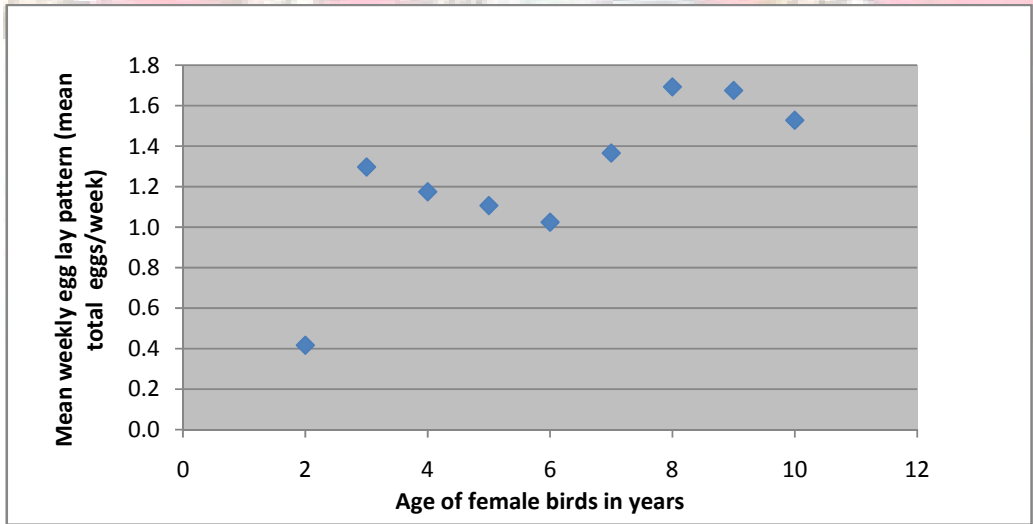
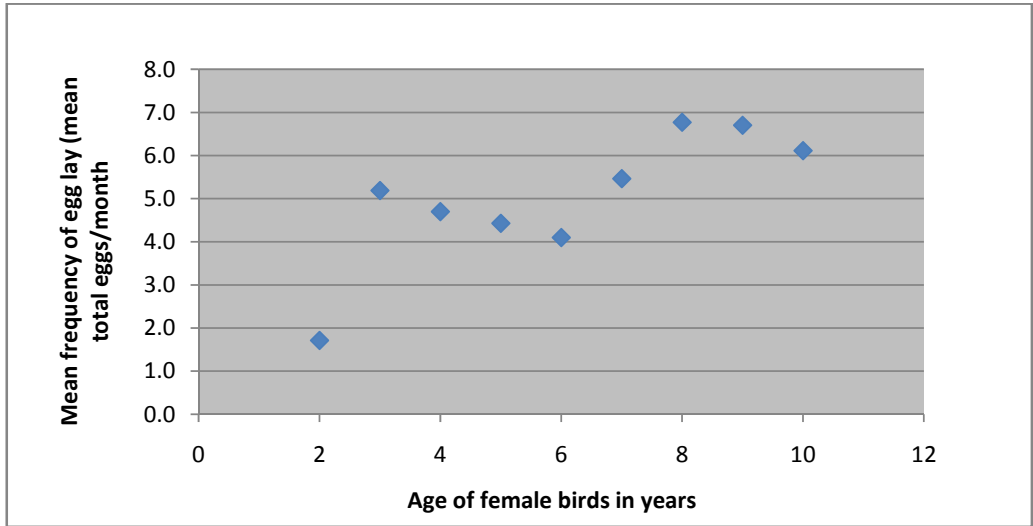
¹se=standard error

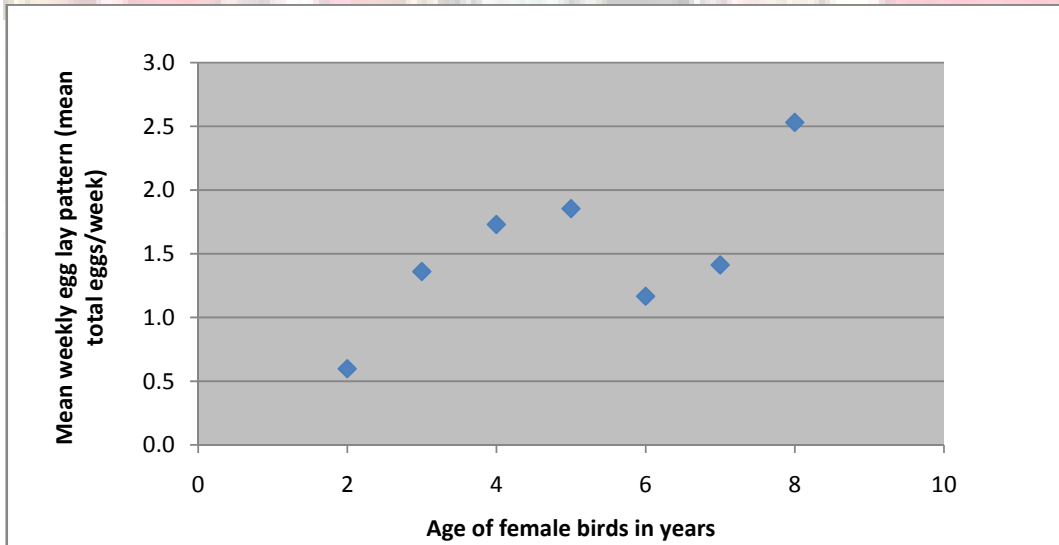
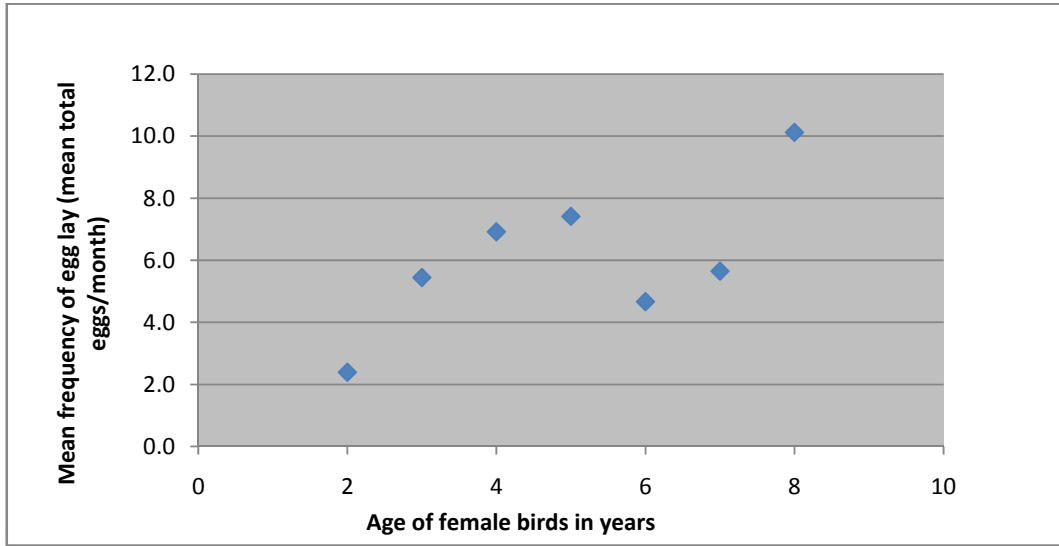
Table 7.11 Weekly laying pattern (eggs/week) for Experiment 3

Treatment (MJ ME/kg feed)	Week 1-4	Week 5-8	Week 9-12	Week 13-16	Week 17-20	Week 21-24	Week 25-28	Mean
8.0	0.7	2.0	2.2	2.5	1.9	2.1	0.5	1.7 ^a
8.7	0.3	2.0	2.2	2.2	2.3	1.8	0.2	1.6 ^a
9.4	0.4	1.7	1.9	2.7	2.6	2.3	0.5	1.7 ^a
10.1	0.9	2.5	2.6	2.6	2.6	2.5	0.7	2.0 ^a
10.8	0.4	1.4	1.3	1.6	1.6	1.8	0.4	1.2 ^a
11.5	0.5	1.2	2.1	2.7	2.1	2.0±	0.4	1.5 ^a
Mean and se¹	0.5±0.2	1.8±0.4	2.0±0.3	2.3±0.3	2.2±0.3	2.1±0.3	0.4±0.1	1.6±0.2

means in columns with same superscript do not differ significantly (P>0.05)

¹se=standard error





Conclusion

This study shows that neither dietary energy nor protein inclusion levels of this study affected the mean frequency of lay (eggs/female/month) and the mean weekly egg laying pattern (eggs/week) of breeding ostriches significantly ($P>0.05$). Dietary protein tended to affect mean frequency of egg laying and the mean weekly egg laying pattern ($P=0.05$). Overall it seems from this studies that eggs were on average laid every 6th (Experiment 1), 5th (Experiment 2) and 5th (Experiment 3) day, which differs greatly in comparison with the laying hen. The maximum frequency of lay (eggs/female/month) for each experiment was 8.0 (Experiment 1), 9.0 (Experiment 2) and 10.6 (Experiment 3). The current research shows that egg production is highly variable among breeding ostriches and erratic in individual breeding ostriches, which is in agreement with studies performed by Bunter *et al.* (2001). No trends or significant regressions could be observed in the study due to the large variation in egg production. It is unlikely that nutrition plays a role in the egg-laying pattern or the high variation in egg production. It seems that genetic-factors contributed to the variation in egg production and erratic lay. The selection of birds with a high breeding value for egg production in order to achieve uniformity in breeding ostriches, seems prudent.

References

- Al-Saffar, A.A. & Rose, S.P., 2002. Ambient temperature and the egg laying characteristics of laying fowl. *World's Poult. Sci. J.* 58, 317-331
- Badley, A.R., 1997. Fertility, hatchability and incubation of ostrich (*Struthio camelus*) eggs. *Poult. Avian Bio. Rev.* 8, 53-76
- Bunter, K.L., Cloete, S.W.P., Van Schalkwyk, S.J. & Graser, H.-U., 2001. Factors affecting reproductive performance in farmed ostriches. *Proc. Assoc. Advmt. Anim. Breed. Genet.* 14, 43
- Hocking, P.M., Gilbert, A.B., Walker, M. & Waddington, D., 1987. Ovarian follicular structure of white leghorns fed *ad libitum* and dwarf and normal broiler breeders fed *ad libitum* or restricted until point of lay. *Br. Poult. Sci.* 28, 493-506
- Malden, C.N., Richard, E.A. & Leslie, E.C., 1979. *Poultry Production*. 12th edition. Philadelphia, Lea & Febiger. pp. 191-252
- Robinson, F.E. & Wilson, J.L., 1996. Reproductive failure in overweight male and female broiler breeders. *Anim F. Sci. Tech.* 58, 143-150
- Scott, M.L., Nesheim, M.C. & Young, R.J., 1969. *Nutrition of the chicken*. M.L. Scott & Assoc., Ithaca, New York
- Weber, G.M., 2009. Improvement of flock productivity through supply of vitamins for higher laying performance and better egg quality. *World's Poult. Sci. J.* 65, 443-458
- Zakaria, A.H., Miyaki, T. & Imai, K., 1984. The relationship of clutch length and egg position on ovarian follicular growth in laying hens. *Poult. Sci.* 63, 1250-1254

Chapter 8

Determination of energy, protein and amino acid requirements for maintenance and egg production of ostriches

Abstract

Great success has been achieved with modelling in quantifying the nutrient requirements of poultry, but modelling has been used only in a few previous studies with ostriches. Results from Chapter 4 and previous studies were used to determine the energy, protein and amino acid requirements for egg production and maintenance. Two methods were used to determine the energy requirement for egg production of ostrich breeding birds. Metabolisable energy requirement for egg production (ME_e) and efficiency of ME utilization for energy deposition in egg (k_o) was calculated as 12.2 MJ/egg and 0.8 respectively. Effective Energy requirement for egg production (EE_e) and maintenance (EE_m) was calculated as 15.9 MJ/bird/day and 17.1 MJ/bird/day respectively. Average total daily protein requirement (TP_t) was calculated as 175g/day.

Keywords: ostriches, efficiency of utilization, modelling

Introduction

Modelling is an appropriate tool to determine the nutrient requirements of animals, but has seldom been used to determine requirements for breeding ostriches. Several trials have been conducted to determine the maintenance (du Preez, 1991; Cilliers, 1994) and egg production (du Preez, 1991) requirements of ostriches. Gous & Nonis (2009) calculated the nutrient requirements for egg production in poultry, these being based on the pattern of laying. This is in turn based on the internal cycle length of the hen, and the weights of the yolk and albumen, which differ as the hen ages. The efficiency of ME utilization for deposition in egg (k_o) for poultry varies between 0.6 – 0.85 (Chwalibog, 1985; Luiting, 1990; Sakomura *et al.*, 2009), but has never been calculated for breeding ostriches before. This should be calculated in order to describe the ability of the ostrich to deposit energy for egg production purposes.

The efficiency of ME utilization for deposition in the egg (k_o) and the ME requirement for egg production (ME_e) was calculated according to a factorial method of Sakomura *et al.* (2009). Values from a study of Brand *et al.* (2005a) were used to determine the Effective Energy (EE) requirement for maintenance based on a model from Emmans & Fisher (1986) and protein and amino acid requirements for maintenance from a model of Emmans (1989). The chemical composition of eggs in Chapter 4 and from Brand (2002) was used to determine the protein and amino acid requirements for

egg production and the EE needed for albumen and yolk deposition. A model from Emmans (1994) was used to calculate the EE needed for albumen and yolk deposition.

Material and Methods

The energy content of the eggs was estimated by a factorial model proposed by Chwalibog (1992). The model was modified by erasing the carbohydrate fraction of eggs, since the carbohydrate portion of eggs is negligibly small and not significant. The energy content of an egg represents the net energy requirement per kilogram of egg produced (Sakomura *et al.*, 2009). The predictions were in turn used to calculate the efficiency of ME utilization for energy deposition in the egg (k_e) and the ME requirement for egg production (ME_e) as used by Sakomura *et al.* (2009) for poultry. The value for the metabolisable energy requirement for maintenance (ME_m) and growth (ME_g) was obtained from Cilliers (1994). Maintenance (ME_m), derived from the value $0.425 \text{ MJ/kg BW}^{0.75}$, was reported as $0.133 \text{ MJ/kg body weight}$ or 14.6 MJ/day and ME_g as $0.012 \text{ MJ/kg body weight}$ or 1.442 MJ/day . Total ME requirement (ME_t) was calculated by the sum of ME_e and ME_m .

A model by Emmans & Fisher (1986) was used to determine the maintenance heat (MH) or maintenance requirement. According to Cilliers *et al.* (1995), the Gompertz model estimated the mature body weight of ostriches at about 120kg. Kritzinger *et al.* (2009) on the other hand reported the maximum weight at maturity as 119.4kg under assumed optimal conditions. The values of the chemical composition of ostriches were obtained from a study of Brand *et al.* (2005a) and applied for a mature ostrich weighting 120kg to determine MH. Various assumptions were made throughout the calculations. It was assumed that there is no difference in the % protein in the body and feathers and feather weight between a 120kg bird and an 80kg bird. Using the equation from Emmans & Fisher (1986):

$MH = M_E \cdot P_m^{-0.27} \cdot P$ (MJ/day; P = body protein weight in kg excluding feathers; P_m = mature protein weight in kg of the ostrich; $M_E = 1.63 \text{ MJ/unit day}$)

A model by Emmans (1994) was used to determine the Effective Energy requirement for egg production (EE_e). Effective Energy requirement for egg production (EE_e) is calculated by the sum of EE needed for albumen deposition (EE_a) and yolk deposition (EE_y). The value of the protein content of the albumen and yolk used was from a study by Brand (2002). Using the equation from Emmans (1994):

$$EE_a = 50(\text{kJ/g protein}) \cdot \text{protein(g)}$$

$$EE_y = 50(\text{kJ EE/g protein}) \cdot \text{protein(g)} + 56(\text{kJ EE/g lipid}) \cdot \text{lipid(g)}$$

Total Effective Energy requirement per day (EE_t) was calculated as the sum of EE_e and MH. The effective energy required for production of one egg is presented as TEE_e . The total Effective Energy requirement (EE_t) was calculated for every month, because the albumen and yolk weight of eggs increased linearly ($P < 0.05$) throughout the season according to Chapter 4, which will influence the requirement on a monthly basis.

Total protein requirement for maintenance (TP_m) was determined by using a model by Emmans (1989). Using the equation from Emmans (1989):

$TP_m = 0.008 \cdot P_m^{-0.27} \cdot P$ (kg/day; P = body protein weight in kg excluding feathers; P_m = mature protein weight in kg of the ostrich; 0.008 = the ideal protein requirement factor for poultry in kg)

The crude protein content (g) of eggs (CP), as calculated in Chapter 4, was used to determine the daily total protein requirement for egg production (TP_e). The amount present in the egg was assumed to be the protein requirement for egg production. An efficiency of utilization factor of 0.7 was used in this calculation. The total protein requirement for formation of one egg is presented as TPE_e .

The total protein requirement (TP_t) was calculated as the sum of total protein requirement for maintenance (TP_m) and total protein requirement for egg production (TP_e). The total protein requirement (TP_t) was calculated for every month, because the crude protein content (g) of eggs on an as-is basis increased linearly ($P < 0.05$) throughout the season according to Chapter 4, which might influence the requirement on a monthly basis.

The amino acid requirement for maintenance (AA_m) were determined by using a model by Emmans (1989). Using the equation from Emmans (1989):

$AA_m = 0.008 \cdot P_m^{-0.27} \cdot P \cdot AAC$ (g/day; P = body protein weight in kg excluding feathers; P_m = mature protein weight in kg of the ostrich; AAC = g amino acid content in 1 kg body protein excluding feathers; 0.008 = the ideal protein requirement factor for poultry in kg)

The amino acid content (g) of eggs (AAC_e), as calculated in Chapter 4, was used to determine the amino acid requirement for egg production (AA_e). The amount present in the egg was assumed to be the amino acid requirement for egg production. An efficiency of utilization factor of 0.7 was used in this calculation. The daily amino requirement for formation of one egg is presented as DAA_e . The total amino acid requirement (AA_t) equals the sum of the amino acid requirement for maintenance (AA_m) and the amino acid requirement for egg production (DAA_e).

To analyze the effect of month and age, an ANACOVA was done using Statistica (2009). Diet was used as the categorical predictor and month and age as the covariate.

Results and Discussion

Table 8.1 provides the energy content (Mcal/kg egg) of eggs (RE_e), efficiency of ME utilization for deposition in the egg (k_o), MJ ME requirement for egg production (ME_e), and total ME requirement (ME_t) (MJ/day), calculated according to a method by Sakomura *et al.* (2009). The age of the birds had no influence ($P>0.05$) on RE_e and k_o . The ME_e calculation does not include the amount of energy needed for shell formation, since its contribution to the overall expenditure is small for egg production, although du Preez (1991) included it in his calculation. Du Preez (1991) reported that 1 kg shell requires 1.2 MJ. It is of interest to note that the month of the season affected k_o ($P<0.05$), tending to decline towards the end of the season, according to ANACOVA, when month was held as the covariate. Linear regression analysis revealed a monthly decline of 0.05 ($y = -0.05x + 0.98$; $R^2 = 0.59$; $P<0.05$). Efficiency of ME utilization for deposition in the egg (k_o) is higher in comparison with poultry, which is 0.64 (Sakomura *et al.*, 2009). The higher efficiency values are unexpected, since the ostrich is not selected yet to be able to extract nutrients as sufficiently as the chicken from the diet. It seems that the energy requirement to produce a kg egg tends to increase during the season. This can possibly be ascribed to impaired efficiency of energy utilization. The pattern of energy deposition in eggs (OE) was also investigated. There was no difference ($P>0.05$) in the ratio between August and December for energy deposited in the egg as fat (OFE) and energy deposited in the egg as protein (OPE). Figure 1 displays the partitioning of energy deposited as protein in the eggs. The age of the birds also had no influence on the OFE:OPE. Although month has no influence on OFE:OPE, the minor changes of this ratio may explain the observed variation in the k_o over the season.

The efficiency of utilisation of an amino acid or of energy could have remained the same amongst birds irrespective of the laying performance of the breeding female ostrich, which is supported by the fact that age had no influence on k_o . All ostrich females might therefore have used the same amount of amino acid and energy to produce one g egg. The only difference amongst individual females is the amount of amino acid and or energy consumed, the amount of energy used for maintenance, which relies on the metabolic rate and thermogenesis of the bird, and the amount deposited in the body as lipid (Fisher *et al.*, 1973).

The ME_t (20.7 MJ ME/day) recommended value in the present study is slightly lower than the proposed value of 22 MJ ME/day of Brand *et al.* (2003). The value in this study should be considered as the minimum daily energy requirement which will not maximise egg production during the season. The daily ME intake of the birds should be set at 22 MJ ME to optimise egg production.

Pectora laborant cultus recti

Table 8.1 The determination of RE_e of ostrich eggs and the k_o , ME_e and ME_t of breeding female ostriches

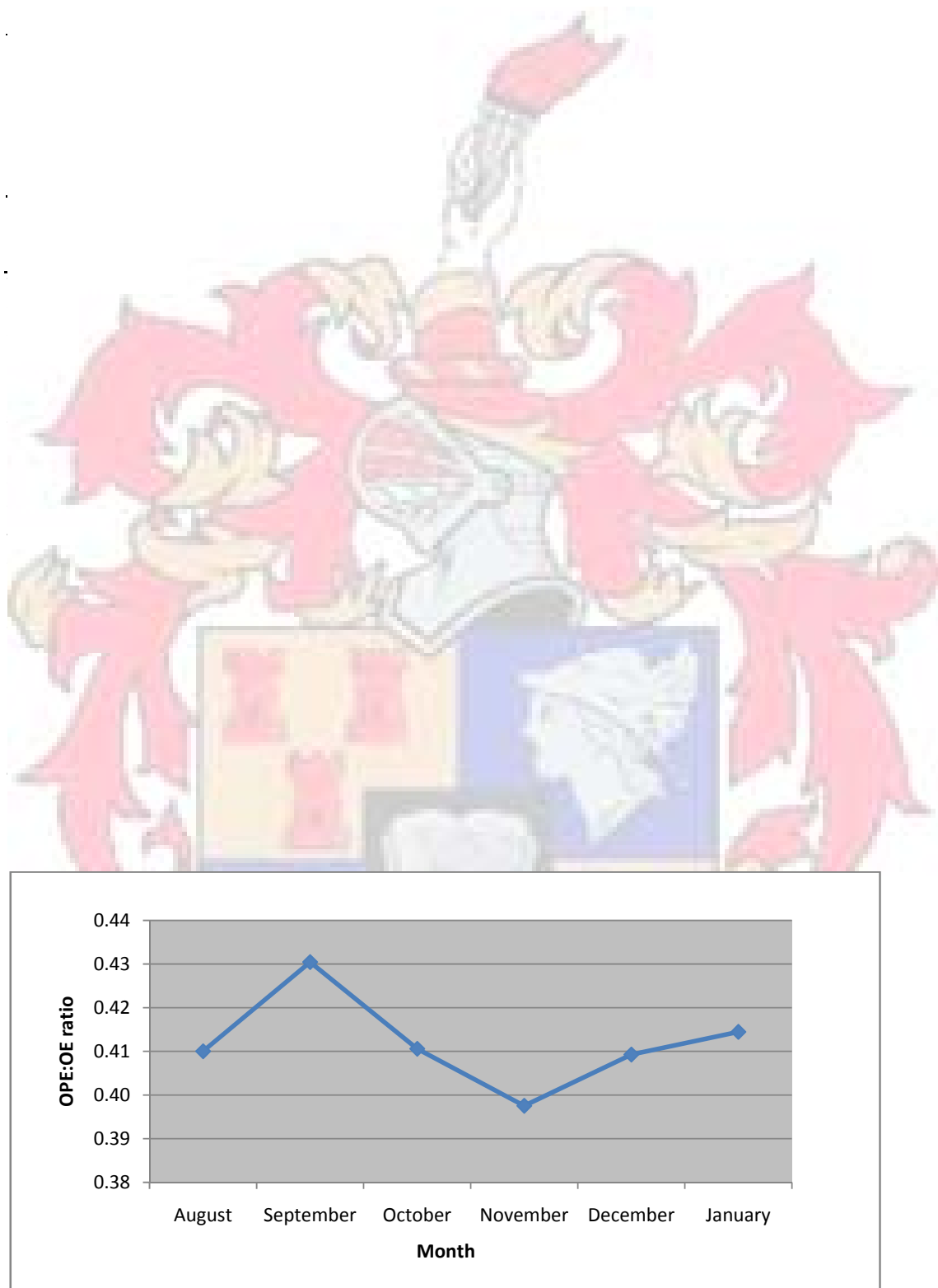


Figure 1 Partitioning of energy deposited as protein in eggs over the season

The total protein requirement for maintenance (TP_m) was calculated as 84g/day. Although the total protein requirement (TP_t) listed in Table 8.2 averages at about 175g/day, it appears that this changes slightly throughout the season. A lower value for total protein requirement per day (175g) were obtained in the present study in comparison with those of du Preez (1991) which were 210g/day. It is of utmost importance to note that the protein requirement reported here applies to a well balanced mixture of essential and non-essential amino acids.

The amino acid requirements for maintenance and egg production (AA_t) are listed in Table 8.3. Lower requirements for egg production (DAA_e) and maintenance (AA_m) were obtained in comparison with those reported by du Preez (1991).

Table 8.2 The total protein requirement for egg production (TP_e) and total protein requirement per egg (TP_t) for each month

Month	Crude protein content of eggs (CP) (g) ¹	TPE_e (g) ²	TP_e (g/day) ³	TP_t (g/day) ⁴
August	113.9	162.7	81.4	165.3
September	127.3	181.9	90.9	174.8
October	131.8	188.3	94.1	178.0
November	125.1	178.7	89.4	173.3
December	128.6	183.7	91.9	175.8
January	134.9	192.7	96.4	180.3
Average	126.9	181.3	90.7	174.6
Standard deviation	7.3	10.4	5.2	5.2

*assuming a 210 day laying cycle, laying an egg every 2nd day

** TP_m (total protein requirement for maintenance)=84g/day

¹Mean CP content of eggs on an as is basis

² TPE_e (total protein requirement for formation of one egg in gram)=CP/0.7 (0.7 being the assumed efficiency of utilisation of dietary protein)

³ TP_e (daily total protein requirement for egg production in gram)= TPE_e /2days

⁴ TP_t (total protein requirement in gram)= TP_m + TP_e



Table 8.3 The amino acid requirements for maintenance (AA_m), egg production (AA_e) and total amino acid requirement (AA_t).

Amino acid	AAC _e (g) ¹	AA _e (g) ²	DAA _e (g/day) ³	AA _m (g/day) ⁴	AA _t (g/day) ⁵
Threonine	3.83	5.47	2.73	2.96	5.69
Arginine	4.31	6.16	3.08	4.87	7.95
Valine	5.33	7.61	3.81	3.94	7.75
Histidine	2.45	3.50	1.75	2.32	4.06
Lysine	6.32	9.03	4.52	5.16	9.68
Methionine	2.86	4.08	2.04	1.47	3.52
Tyrosine	5.74	8.20	4.10	1.88	5.98
Isoleucine	3.34	4.78	2.39	3.45	5.84
Phenylalanine	3.46	4.95	2.47	3.22	5.70
Leucine	8.50	12.2	6.07	5.28	11.4

*assuming a 210 day laying cycle, laying an egg every 2nd day

¹AAC_e=amino acid content of eggs on an as is basis

²AA_e(amino acid requirement for formation of one egg in gram)=AAC_e/0.7 (0.7 being the assumed efficiency of utilisation of dietary protein)

³DAA_e(daily amino acid requirement for egg production in gram)=AA_e/2days

⁴AA_m(amino acid requirement for maintenance in gram)=8*P_m^{-0.27}*P*AAAC (g/day; P = body protein weight in kg excluding feathers; P_m = mature protein weight in kg of the ostrich; AAC = g amino acid content in 1 kg body protein excluding feathers; 8 = the ideal protein requirement factor for poultry in g) (Emmans, 1989)

⁵AA_t (total amino acid requirement in gram)=AA_m+DAA_e

The dietary percentage crude protein and amino acid needed to meet the requirements for maintenance and egg production can be calculated by using the values given in Tables 8.2 and 8.3. It has been proved in Chapter 5 that breeding ostriches eat at an average rate of 3.7kg/bird/day under an *ad libitum* situation. Chapter 5 also concluded that the feed intake of the birds is not influenced by the dietary content. Further assumptions applies that the bird lays an egg every second day during the season. The maximum frequency of egg laying that was recorded in Chapter 7 was 1 egg every 2.6 days. Brand *et al.* (2005b) reported the ileal protein digestibility value for ostriches as 64.7%, determined by the ileo-rectal anastomosis technique, which is a more superior technique than ileal digestibility trials (Fuller & Livingstone, 1982). Emmans & Fisher (1986) recommended an efficiency factor for protein of 0.7. The calculated dietary percentage crude protein needed to meet the requirements for maintenance and egg production will be displayed below as an example. The dietary percentage crude protein and amino acid needed to meet the requirements for maintenance and egg production is subsequently given in Table 8.4.

The crude protein content of average sized egg is 126.9g. The crude protein content of the egg is assumed to be the requirement for egg production as mentioned previously. Because the hen layed an egg every second day, it required only half the crude protein content of the egg every day. Thus, 126.9g/2days=63.5g/day. The protein requirement for maintenance is 83.9g/day. The daily dietary percentage crude protein needed for maintenance and egg production (TP_T) can be calculated as follow, assuming a feed intake of 3kg, laying an egg every second day, the ileal protein digestibility

value for ostriches as 64.7% and a efficiency factor of 0.7. An efficiency factor is already incorporated in the model of Emmans (1989) which determined the maintenance requirements.

$$TP_T (\%) = [(63.5/3000)*100]*1.54*1.43 + [(83.9/3000)*100]*1.54$$

$$TP_T (\%) = 9.1 \text{ \% dietary crude protein}$$

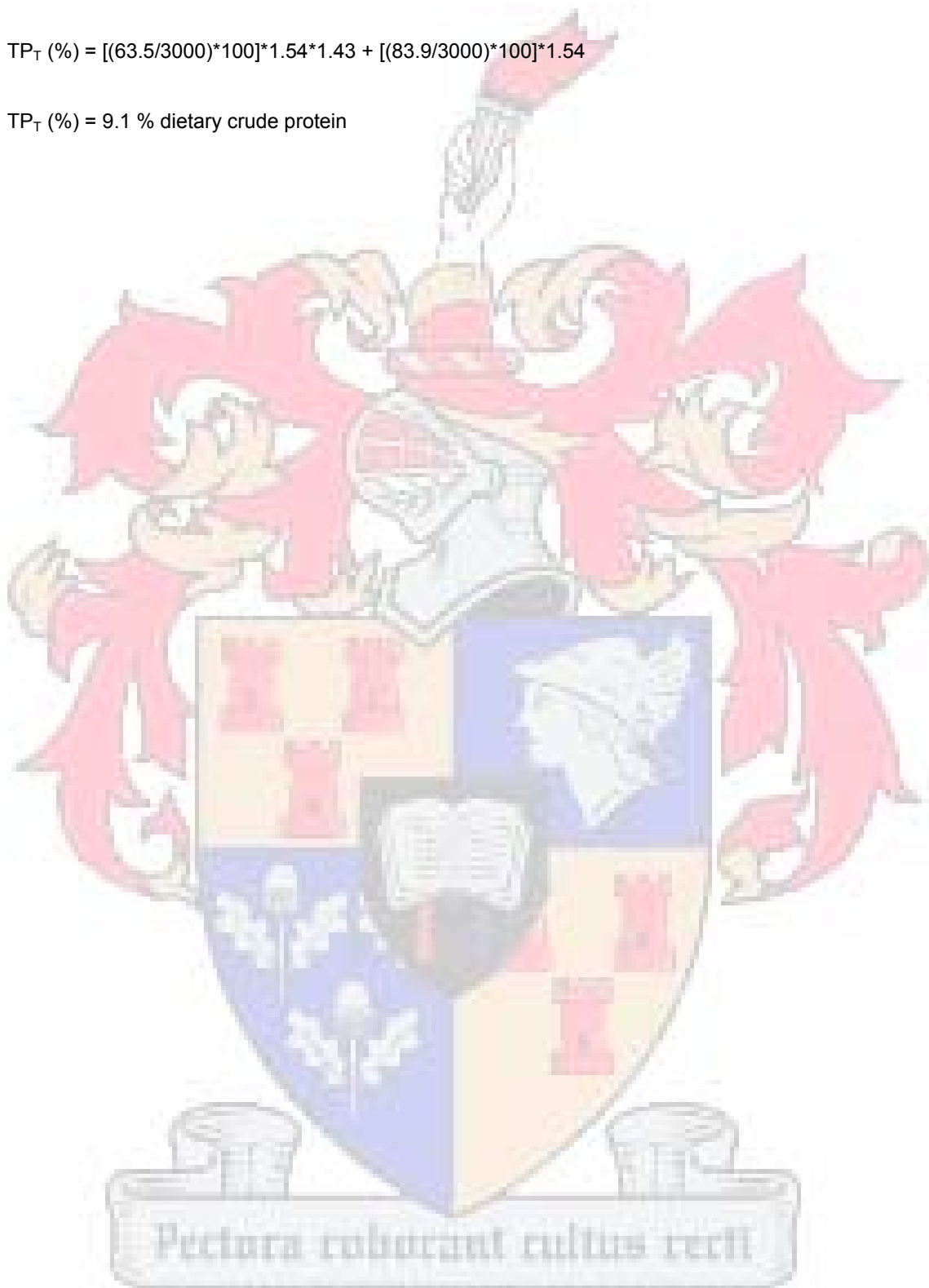


Table 8.4 The dietary percentage crude protein and amino acid needed to meet the requirements for maintenance and egg production

Nutrient	Content/egg (g)¹	Maintenance requirement (g/day)	Daily dietary requirement (%) at 2kg feed/day	Daily dietary requirement (%) at 2.5kg feed/day	Daily dietary requirement (%) at 3kg feed/day
Crude protein	126.9	83.90	11.30	9.88	8.95
Threonine	3.83	2.96	0.36	0.32	0.29
Arginine	4.31	4.87	0.49	0.44	0.41
Valine	5.33	3.94	0.49	0.44	0.40
Histidine	2.45	2.32	0.25	0.23	0.21
Lysine	6.32	5.16	0.61	0.54	0.50
Methionine	2.86	1.47	0.23	0.20	0.18
Tyrosine	5.74	1.88	0.41	0.35	0.31
Isoleucine	3.34	3.45	0.36	0.32	0.30
Phenylalanine	3.46	3.22	0.36	0.32	0.29
Leucine	8.50	5.28	0.74	0.64	0.58

*assuming a 210 day laying cycle and laying an egg every 2nd day

¹mean crude protein and amino acid content of eggs on an as is basis



The energy requirement for maintenance was calculated as 17.1 MJ/day. Cilliers (1994) calculated the EE_m value for 7 month old ostriches as 8.9 MJ/day.

The EE_e requirement for the different months is presented in Table 8.5. These values apply to breeding female ostriches of all ages because the proportion of albumen and yolk and egg composition remains unchanged at different ages according to Chapter 4. This is different from broiler breeders, where the composition of eggs changes systematically with age (Johnston & Gous, 2007).

Table 8.5 Effective Energy requirement for egg production (EE_e) and total Effective energy requirement (EE_t) for each month

Month	Egg weight (g)	TEE_e (MJ/egg) ¹	EE_e (MJ/day) ²	EE_t (MJ/day) ³
August	1264	29.0	14.5	31.6
September	1347	31.1	15.6	32.7
October	1370	31.6	15.8	32.9
November	1340	31.0	15.5	32.6
December	1424	33.3	16.7	33.8
January	1511	35.3	17.7	34.8
Average	1376	31.9	15.9	33.0
Standard deviation	83.8	2.2	1.1	1.1

*assuming a 210 day laying cycle, laying an egg every 2nd day

¹ EE_m (effective energy requirement for maintenance per day in MJ)=17.1 MJ/day ($EE_m=M_E \cdot P_m^{-0.27} \cdot P$; MJ/day; P = body protein weight in kg excluding feathers; P_m = mature protein weight in kg of the ostrich; M_E = 1.63 MJ/unit day) (Emmans & Fisher, 1986)

² TEE_e (total effective energy requirement for formation of one egg in MJ)= EE_a (effective energy requirement for albumen formation in MJ)+ EE_y (effective energy requirement for yolk formation in MJ); EE_a = 50(kJ/g protein)*protein(g); EE_y = 50(kJ EE/g protein)*protein(g) + 56(kJ EE/g lipid)*lipid(g) (Emmans, 1994)

³ EE_e (daily effective energy requirement for egg production in MJ)= $TEE_e/2$ days

⁴ EE_t (total effective energy requirement in MJ)= EE_e + EE_m

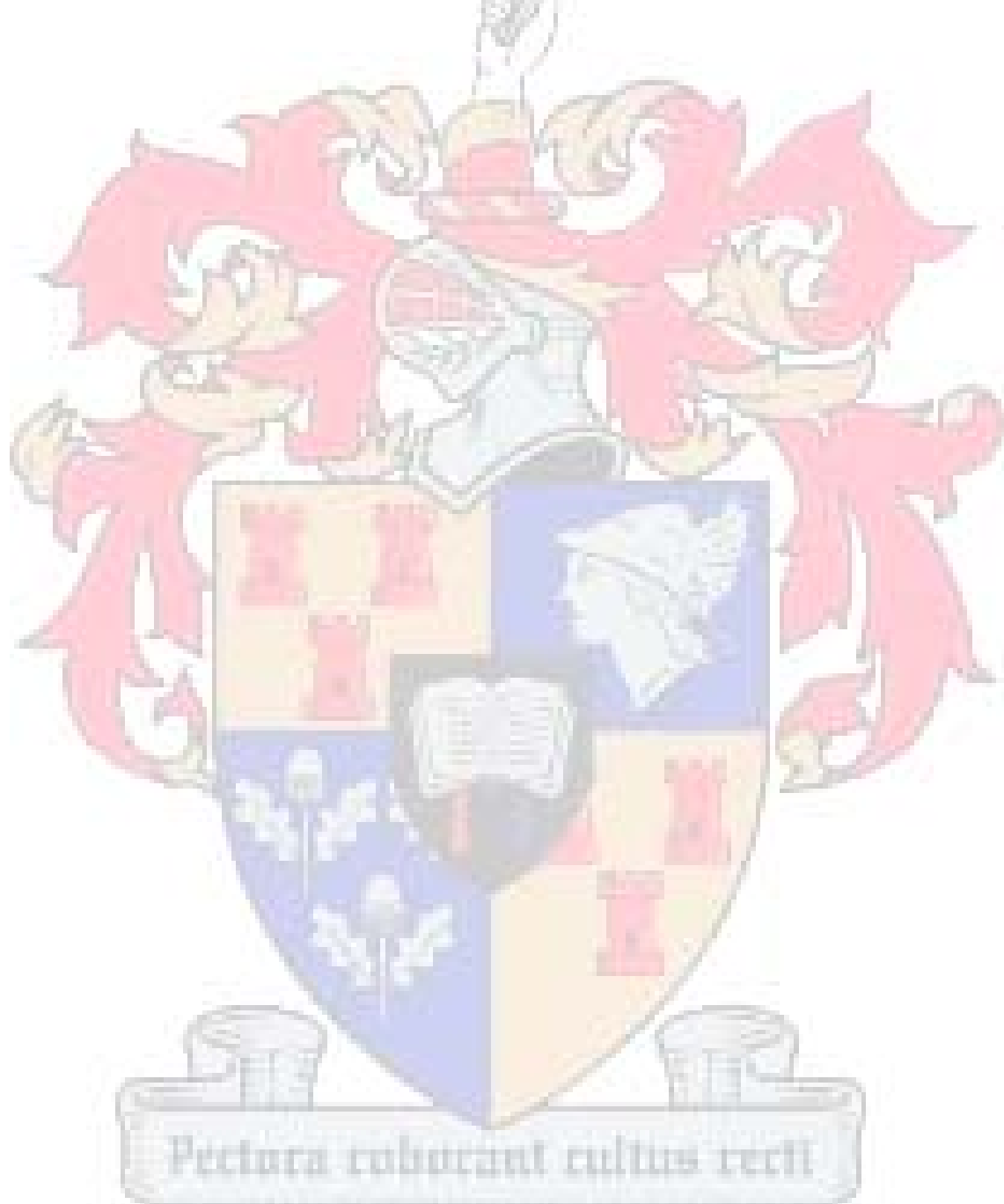
Conclusion

Previous studies have revealed that a daily ration below 22 MJ ME per bird per day will probably result in lower egg production (Brand *et al.*, 2003), while the current study suggests that the minimal total energy requirement to produce an average size egg is 20.7 MJ ME/day. Mean ME_e and k_o were determined respectively as 12.2 MJ ME/egg produced and 0.8, although the ME_e and k_o changes over the season. Nutritionists should not be oblivious of the varied ME_e and k_o and ration formulation should definitely take these EE factors into consideration. Ostriches have an excellent ability to deposit dietary energy in the egg. Average total daily protein requirement for maintenance and egg production (TP_t) was calculated as 174.6g/day. Amino acid requirement for maintenance and egg production were calculated and is lower than the values of du Preez (1991). The average EE_e /day was calculated as 15.9. Two methods were used in this study to determine the energy requirement for egg production.

References

- Brand, Z., 2002. The effect of energy and protein nutritional levels on production of breeding ostriches. MSc Thesis. Rhodes University, South Africa
- Brand, Z., Brand, T.S. & Brown, C.R., 2003. The effect of dietary energy and protein levels on production in breeding female ostriches. *Br. Poult. Sci.* 44, 598-606
- Brand, T.S., Gous, R.M., Kruger, A.C. & Aucamp, B.B., 2005a. The chemical and amino acid composition of whole ostrich carcasses at different growth stages. *Proc. 3rd Int. Rat. Sci. Symp.* 14-16 October 2005, Madrid, Spain
- Brand, T.S., van der Walt, J.G. & Brand, Z., 2005b. The ileal protein digestibility values of diets for ostriches determined with ileum-rectum anastomosis ostriches. *Proc. 3rd Int. Rat. Sci. Symp.* 14-16 October 2005, Madrid, Spain
- Chwalibog, A., 1985. Studies on Energy Metabolism in Laying Hens. *Statens Husdyrbrugsforsog, Beretning 578*, Denmark
- Chwalibog, A., 1992. Factorial estimation of energy requirements for egg production. *Poult. Sci.* 71, 509-515
- Cilliers, S.C., 1994. Evaluation of feedstuffs and the metabolisable energy and amino acid requirements for maintenance and growth in ostriches (*Struthio camelus*). PhD thesis. University of Stellenbosch, South Africa
- Cilliers, S.C., du Preez, J.J., Maritz, J.S. & Hayes, J.P., 1995. Growth curves of ostriches (*Struthio camelus*) from Oudtshoorn in South Africa. *Anim. Sci.* 61, 161-164
- Du Preez, J.J., 1991. Ostrich nutrition and management. In: *Recent Advances in Animal Nutrition in Australia*. Ed. Farrell, D.J., University of New England, Armidale, Australia. pp. 278-291
- Emmans, G.C., 1989. The growth of turkeys. In: *Recent advances in turkey science, Poultry Science Symposium No. 21*. Butterworths, London. pp. 135-166
- Emmans, G.C., 1994. Effective energy: a concept of energy utilization applied across species. *Br. J. Nutr.* 71, 801-821
- Emmans, G.C. & Fisher, C. 1986. Problems in nutritional theory, *Poultry Science Symposium No.19*. In: *Nutrient requirements of poultry and nutritional research*. Ed. Fisher, C. & Boorman, K.N., Butterworths, London. pp. 9-39
- Fisher, C., Morris, T.R. & Jennings, R.C., 1973. A model for the description and prediction of the response of laying hens to amino acid intake. *Br. Poult. Sci.* 14, 469-484
- Fuller, M.F. & Livingstone, R.M., 1982. Annual report of studies in Animal Nutrition and Allied Science. Rowett Research Institute, Vol. 39
- Gous, R.M. & Nonis, M.A., 2009. Modelling egg production and nutrient responses in broiler breeder hens. *J. Ag. Sci.* in Press.
- Johnston, S.A. & Gous, R.M., 2007. Modelling the changes in the proportions of the egg components during a laying cycle. *Br. Poult. Sci.* 48, 347-353

- Kritzinger, W.J., Brand, T.S., Hoffman, L.C. & Mellett, F.D., 2009. A description of body composition change in ostriches (*Struthio camelus*) under optimal feeding conditions. South Africa Society of Animal Science's 43rd Congress, 28-30 July 2009, Bergville, South Africa
- Luiting, P., 1990. Genetic variation of energy partitioning in laying hens: causes of variation in residual feed consumption. *World's Poult. Sci. J.* 46, 133-152
- Sakomura, N.K., Siqueira, J.C. & Gous, R.M., 2009. The use of modelling to determine nutrient requirements of poultry. *Proc. 28th Sci. Day.* 8 October. Pretoria, South Africa



Chapter 9

General conclusion and future prospects

In this research study various production studies were performed in order to quantify how breeding ostriches respond to different dietary energy and protein levels. In another study, the growth of the reproductive organs and liver of female breeding ostriches was examined in order to gain data for model development. This study provides an description of the nutrient requirement of the breeding female ostrich.

Dietary protein and energy had no effect on egg production at the feed intake levels used in this study. The age of the birds had an important effect on production data. Chemical analysis of the eggs revealed that the breeding female ostrich deposited more protein in the eggs that are laid in the later clutches during the laying cycle. A recommendation would be to make use of more egg sample to obtain a better understanding of the deposition of nutrients in the eggs that are laid later during a single laying cycle.

The average total daily protein requirement for maintenance and egg production (TP_1) was calculated as 174.6g/day, which is lower than the value proposed by du Preez (1991). The amino acid requirements for maintenance and egg production is also provided, which is also lower than the values determined by du Preez (1991). The average ME_e to produce an average size egg (1.39kg) is 12.2 MJ ME as found in this study, but this value should be changed every month during the season to a maximum of 13.9 MJ ME in the last month. The total average MJ ME needed per day (20.7 MJ) is slightly lower than the values of 22 MJ ME/day proposed by Brand (2008) and 23 MJ ME/day by du Preez (1991). The average k_e value is reported as 0.8. Breeding ostriches have an excellent ability to extract energy from the diet for egg production purposes, but this ability is impaired towards the end of the season, probably due to minor changes in the OFE:OPE. The requirement for energy is not fixed, and is different for every month. Future energy research might be aimed at determining the partial efficiencies of protein and fat energy for ostriches. Breeding ostriches do not have the ability to regulate their feed intake at any dietary energy level as used in this study, which was unexpected. The possibility exists that other unknown factors may have influenced feed intake.

The growth studies of the reproductive organs and liver revealed that the breeding female ostrich might need additional protein during the first seven weeks of the breeding season. The current study does not provide evidence as to whether the reproductive organs grow during the rest period or when they start growing. This aspect should be investigated in future research. The growth of the reproductive organs in the current study was not uniform, which makes it difficult to indicate the tendency of the growth of the ovary and oviduct, and to fit a suitable model like the Gompertz curve. A recommendation would be to make use of more observations in order to prove beyond doubt whether the organs grow significantly or not, since only a small number of birds were slaughtered in this study.

Dawson *et al.* (1986) and Foster *et al.* (1987) stated that an increase in the photoperiod resulted in the maturation of the gonads. This should be investigated to determine to what extent the photoperiod influences the growth of the female's reproductive organs. These studies are useful in order to develop a model, which can subsequently be used to determine the nutrient requirements of breeding ostriches (Brand & Gous, 2006).

The current study focused mostly on energy and protein requirements. Very little evidence exists as to the vitamin and mineral requirements of breeding ostriches. The importance of these nutrients should not be neglected and research is needed in this area.

The high variation in production levels among breeding ostriches and the low survival rate of chicks remains a major concern for researchers. Seasonal effects and the age of the birds also play a major role in the observed variation. A formidable task still lies ahead to establish the unknown information of breeding ostriches. The implementation of a formal breeding plan will be a major breakthrough in research and will result in more uniformity. Future research needs to convey whether production is related to the nutrition and other factors during the pre-lay or rest period. Factors that are worth studying include the body composition of breeding birds. Gous (1972) stated that the body composition of a bird before lay has an influence on the laying capabilities of that bird.

References

- Brand, T.S., 2008. Volstruisvoeding: 'n Wetenskaplike benadering. Sun Print, University of Stellenbosch, Stellenbosch. pp. 48
- Brand, T.S. & Gous, R.M., 2006. Feeding Ostriches. In: Feeding in domestic vertebrates: From structure to behaviour. Ed. Bels, V., CAB International, Wallingford, England. pp. 136-155
- Dawson, A., Goldsmith, A.R., Nicholls, T.J. & Follett, B.K., 1986. Endocrine changes associated with the termination of photofractoriness by short daylengths and thyroidectomy in starlings (*Sturnus vulgaris*). J. Endocrinol. 110, 73-79
- Du Preez, J.J., 1991. Ostrich nutrition and management. In: Recent Advances in Animal Nutrition in Australia. Ed. Farrell, D.J., University of New England, Armidale, Australia. pp. 278-291
- Foster, R.G., Plowman, G., Goldsmith, A.R. & Follett, B.K., 1987. Immunohistochemical demonstration of marked changes in the LHRH system of photosensitive and photorefractory European starlings (*Sturnus vulgaris*). J. Endocrinol. 115, 211-220
- Gous, R.M., 1972. The influence of dietary protein and energy concentration on the body composition of broiler breeder pullets. S. Afr. J. Anim. Sci. 2, 51-58

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