THE EFFECT OF ENERGY AND PROTEIN NUTRITIONAL LEVELS ON PRODUCTION OF BREEDING OSTRICHES

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DECLARATION

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

Z BRAND 01 January 2002

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ABSTRACT

Adequate and appropriate nutrition is essential for the production of high quality commercially farmed animal species. Although South Africa has had a well-established ostrich industry for over a century, little information on ostrich nutrition, in particular the specific nutritional requirements at different stages of production, is available. The industry has consequently relied heavily on data derived from poultry and pigs, but this has often proved to be unsatisfactory for ostriches and has resulted in serious nutritional-related problems. Recent studies on the metabolisable energy of specific components of diet formulations and balanced diets have indicated that ostriches have enhanced digestibility compared with poultry and pigs. At the same time, in the present economic climate, it is necessary to find cost-effective diets for breeding birds without compromising egg and chick production. This study primarily assessed the effect of different dietary protein and energy levels on production parameters and body condition of breeding female and male ostriches. The energy content of the diet appears to be the main constraint to egg production and breeders on low energy diets laid fewer eggs and lost more body condition compared with breeders fed higher energy diets. A diet with 8.5 MJ/kg DM and 10% protein with well balanced amino acids appears to be sufficient for female breeders without compromising production and a diet with 7.5 MJ/kg DM and 10% protein appears suitable for breeding male ostriches. Different dietary energy and protein levels similarly had little or no effect on egg quality and composition. This study also assessed the carry-over effect of the nutritional regime in one year on the production in the following breeding season. Females fed diets as low as 7.5 MJ/kg ME in the previous breeding season produced significantly fewer eggs in the next breeding season, which resulted in lower chick production. Energy had no effect on the percentage infertile eggs or on the initial egg weight. Different levels of dietary protein had no effect on egg production, egg weight, fertility, hatchability and initial chick weight.

CHAPTER 1

INTRODUCTION

HISTORICAL BACKGROUND: THE DEVELOPMENT OF THE OSTRICH INDUSTRY IN SOUTH AFRICA

Ostrich farming as a commercial enterprise in South Africa started between 1857 and 1864 (Smith 1963). According to a census of the Cape Colony, there were 80 domesticated ostriches in 1865, 32 247 in 1875 and 253 463 by 1895 (Van Zyl 1996a). At this stage, ostrich feathers were the main commercial product and were highly prized by the European fashion industry. The quality of feathers from the Cape ostriches was, however, not particularly good and birds were consequently imported from Tripoli, Syria, Algeria, Morocco and Tunisia to improve the local strain through crossbreeding (Van Schalkwyk 1998). By 1913 ostrich feathers were ranked fourth in value on the list of exports from South Africa after gold, diamonds and wool. World War I brought about a worldwide depression and between 1914 and 1918 the South African ostrich feather industry collapsed (Smith 1963).

In the 1940's a resurgence of interest in ostriches as a commercial farming enterprise occurred when the quality of ostrich hides for leather products was discovered. In 1945 the Little Karoo Agriculture Co-operative was established in Oudtshoorn to regulate the revitalised industry and on 1 August 1959 the Co-operative gained control over the disposition of all ostrich products in South Africa. The industry became protected by law as a national asset, a single channel for marketing ostrich hides was established, and it became illegal to export from South Africa any ostrich genetic material as eggs or live birds. During this period an increase in ostrich meat products resulted in a boom in the trade of biltong (dried meat) and the ostrich became recognized as a credible competitor in the red meat market because of its healthy, lean qualities. In 1965, the Co-operative built an abattoir in Oudtshoorn, although the hides continued to be sent to London for tanning until a tannery was built in 1970 for the export of finished ostrich leather. With increasing interest in ostrich products, an increase in prices followed which led to the development of new ostrich farming areas in South Africa. On 26 October 1993 the ostrich industry in South Africa was deregulated and the National Ostrich Producers Association was formed in May 1994. The purpose of the association was to develop the industry on a national basis. Although ostrich farming has expanded throughout South Africa, the Little Karoo is still the center of ostrich farming in the country and it is the main source of income for most farmers in the area.

Ostrich products are primarily fashion products and the world market is consequently relatively small. These factors limit the prospects of the industry for expansion and make it sensitive to the vagaries of supply and demand. Many newcomers to the industry did not consider its complexity and the high capital input required. This was especially true overseas where there was a lucrative market for breeding material. Once the market was saturated, producers realized that the emphasis within the industry would have to shift from breeding to the production of products. In 1997 the supply of ostrich products began to outstrip the demand and prices plunged as stockpiles of unsold hides appeared. Income per slaughter bird dropped for R2 000/bird to between R700 and R1 000/bird. Not since the collapse of the feather industry had prices for ostrich products, particularly leather, fallen so quickly and to such record lows. The Klein Karoo Co-operative consequently implemented a quota system to limit the quantity of birds offered for slaughter. This new quota, together with falling prices, put enormous strain on the farmers and many had to find alternatives to ostrich farming as their primary source of income. The quota system, however, bore fruit and the surplus of hides rapidly decreased. During the year 2000 about 250 000 birds were slaughtered throughout South Africa, approximately 65% of which were slaughtered at the Klein Karoo Co-operative's abattoir in Oudtshoorn. There are currently about 35 000 breeding pairs of ostriches in South Africa with about 65% of these situated within the Little Karoo farming area. Approximately 900 of the 1 400 ostrich farmers in South Africa are found within the Little Karoo (W.P Burger, pers. comm.). Switzerland is currently the largest importer of ostrich meat, while Japan and USA are the largest importer of tanned ostrich skins (Van Zyl, 1996b).

THE OSTRICH INDUSTRY IN OTHER COUNTRIES

Ostrich production has become an international industry. Although South Africa remains by far the most important country, Israel has become the other major producer. There are about 30 000 ostriches on about 30 farms in Israel. Large quantities of eggs are annually exported to the USA and Europe (Van Zyl 1999) and three abattoirs process ostrich meat. Because Israel does not presently have any tanneries, raw hides are exported and distributed throughout Europe.

In 1987, 20 ostrich farmers in Zimbabwe formed The Ostrich Producers Association of Zimbabwe (TOPAZ). There are currently about 5 000 ostriches in Zimbabwe and the ostrich producers export meat, tanned or crust skins and, to a small extent, finished leather goods, to Europe, Singapore and Japan (Van Zyl 1996c, Van Zyl 1999). Production in other parts of the world became possible when Namibia achieved independence and began exporting eggs and live birds. According to the American Ostrich Association there were between 7 000 and 10 000 ostrich farmers in the USA in 1996 (Van Zyl 1996b) with about 25% of the industry being located in the state of Texas. The ostrich industry in the USA, however, collapsed during 1997. Although ostriches are farmed in Canada, it cannot currently be considered as a viable commercial competitor because the numbers of breeding birds are still to low (Van Zyl 1996b). For the industry to do well in Canada there has to be improvement in fertility levels and the survival rates of chicks, as well a significant decrease in production costs.

Since 1990 ostrich farming has developed in Europe and is mainly active in the United Kingdom, Belgium, Holland and France (Van Schalkwyk 1998). There has been significant growth in the ostrich market in Belgium and the neighboring countries in the last few years. Approximately 7 000 ostriches are farmed throughout Europe and about 30 000 ostriches in the Middle and Far East. Initially, as in North America, the European market was for breeding birds but a transition towards a slaughter market has occurred over the last year or so, a situation that could be aided by the 2001 foot-and-mouth crisis. Because of its healthy qualities, there is a reasonable level of demand for ostrich meat in many countries of Europe, but this is currently being met predominantly from outside the European Union (Adams and Brian 2000). Despite the lack of official support and experience in the UK and elsewhere, over eight years of rearing ostriches has formed the basis of a sustainable industry, combining production, processing and marketing within the EU itself.

Commercial ostrich breeding was introduced a decade ago in the Guangdong province of China and now is developing rapidly across the rest of the country. Between 1994 and 1996, China spent US$100 million to import about 8 000 purebred ostriches and 50 000 eggs (Van Zyl 1996b). According to the China Ostrich Breeding and Development Association there are about 200 ostrich/emu farms and about 20 000 ostriches/emus nationwide. The market for ostrich meat and byproducts is very limited in China because of high prices for products and lack of consumer awareness. Output of ostrich skins and leather is currently small because of inadequate facilities and processing techniques.

The market in Australia started on a small scale and was based primarily on a market for breeding birds. With the help of the appointed Australian Ostrich Association (AOA) the industry has expanded rapidly and there are currently about 35 000 ostriches in Australia. A limited slaughter program was started by the AOA in 1996 and all research on ostriches is largely funded by the AOA with minimal government assistance (Van Zyl, 1996b).

THE EFFECT OF NUTRITION ON THE REPRODUCTION OF BIRDS

Nutrition is an important factor affecting reproduction in birds (Carey 1996). It may play a particularly important role at the onset and during the breeding season, especially in females where additional energy, protein and specific nutrients may be required for egg production.

Which of these are potentially limiting factors in egg production and egg quality is, however, equivocal. The availability of dietary protein in particular has been suggested to act as both a proximate and indirect factor influencing foraging behaviour, clutch size, egg quality, and the allocation of lipid and protein stores in laying birds (Carey 1996). Studies on several species of wild birds have indicated that dietary protein supplementation results in increases in egg size and egg quality. Williams (1996) and Ramsey *et al.* (1997) found that females receiving protein-supplementation, laid lager eggs than the control. The increase in egg size involved the increase in both yolk and albumen content. Similarly, protein limitation results in reduced egg weight and quality and a loss of weight in laying females as body protein reserves decline (Houston *et al.* 1983). In contrast to protein, energy supplementation of diets of laying birds appears to have little effect (Bolton *et. al.* 1992, Williams 1996, Ramsey & Houston 1997) except possibly in nutrient-poor environments (Nager *et al.* 1997). The potential importance of specific nutrient availability as a limiting factor was illustrated by the analysis of the amino acid demands for egg production (Murphy 1994).

Adequate and appropriate nutrition is particularly important in domesticated poultry species where sustained egg or chick production is a factor. In many cases, poultry are fed on high protein and energy diets to enhance production, although the value of this appears questionable. Several studies suggest that feeding laying hens on high protein diets has either no significant effect on egg production or can depress egg production and reduce fertility (Malden *et al.* 1979, Goerzen *et al.* 1996, Scott *et al.* 1999). There are indications that higher protein diets result in body protein reserves that subsequently enhance egg size (Summers *et al.* 1994) but pre-lay feeding of low protein diets to hens resulted in only a slight reduction in egg weight and had no effect on the rate of egg production (Summers 1993). In Turkey hens, protein intake was significantly reduced in birds allowed to select their diets compared to those fed a "balanced" diet. Although there was no difference in body weight, egg production or egg weight of turkey hens on the self-selection diet, fertility and hatchability of eggs produced was significantly lower compared to that of turkey hens consuming the control diet (Emmerson *et al.* 1991). While most studies have focused on the role of nutrition on egg production and quality of the female, nutrition potentially also affects male productivity. This aspect has received relatively little attention, although Cecil (1982) found that semen concentration from male turkeys was similar when collected from males consuming diets with protein levels between 8 and 17% and that fertility and hatchability of eggs did not differ between the treatments.

Energy supplementation in laying hens has been shown to improve food conversion rates but had no significant effect on the rate of egg production or on egg weight (Grobas *et al.* 1999).

Laying hens have also been shown to regulate food consumption according to the energy content of the diet, with hens on low energy diets consuming 50% more food than hens on high-energy diets (Malden *et al.* 1979). Similarly, Waldie *et al.* (1991) found that the food intake of pigeons decreased with an increase in dietary energy level. This resulted in a similar total energy intake for birds on the different diets. In contrast, Rosebrough *et al.* (1983) found that the efficiency of energy utilization by turkey hens for both egg and poult production was greater in diets with lower energy and lower protein levels.

The effects of diet supplementation on egg production and quality are only significant if they affect the weight, growth and survival of the hatchlings. These effects are, however, equivocal and may only influence chick fitness soon after hatching. In studies done by Ramsey *et al.* (1997), Williams (1994) and Carey (1996) no significant difference in chick survival was found between supplemented- and non-supplemented groups.

NUTRITIONAL RESEARCH IN OSTRICHES

Ostrich production is a relatively new commercial farming enterprise in many countries and relatively little scientific information is available on many aspects of ostrich biology. The expansion of the ostrich industry has necessitated greater knowledge about their welfare (Mitchell 1999), behavioural needs (Sambraus 1994) and their nutritional requirements (Janssens *et al.* 1997). In 1913 the first book on ostrich nutrition was published in South Africa (Dowsley and Gardiner 1913) but relatively little data has accumulated since then. Information on nutritional requirements, in particular the true metabolisable energy of different dietary ingredients and amino acid requirements for maintenance and growth has recently been reviewed (Cilliers & Angel 1999). These authors also highlighted how little is known about the nutritional requirements or metabolic adjustments in breeding ostriches, in particular laying ostrich hens. Because of the general lack of scientific data on the nutritional needs of ostriches, data for poultry have been extrapolated to develop nutritional strategies for ostriches. Studies of ostrich anatomy and digestive function have established that the ostrich can be considered to be a large avian herbivore (Ullrey *et al.*1996). They have a crop, which is the food storage organ in other avian species, a role served in ostriches by the large proventriculus and gizzard (Angel 1996, Scheideler 1996, Bezuidenhout 1999). Ostriches in the wild prefer low-growing, green plant food and rarely ingested dead or woody material (Williams *et al.* 1994, Milton *et al.* 1994). This observation is consistent with the large chamber in the hindgut of ostriches that is specialized for fermentative digestion, as indicated by its large capacity, neutral pH, and high concentration of volatile fatty acids (VFA), low lactic acid and a high NH_3-N (Swart *et al.* 1993). The VFA production rates in the hindgut of the ostrich are typical of those reported for ruminants and ruminant-like herbivores. The absorption and oxidative metabolism of end products from cellulose fermentation were demonstrated to contribute to the ME requirement of growing ostriches and the energy contribution from volatile fatty acids could be as high as 76% of the ME requirement of ostriches.

Some of the problems associated with obesity in the practical farming of ostriches are probably due to the underestimation of utilization by ostriches of diets formulated using metabolisable energy (ME) values derived from poultry (Angel, 1996). The differences in digestion and metabolism between ostriches and poultry required the re-assessment of nutritional values of various ingredients to establish a new system for ostrich feed evaluation. Cilliers (1994) conducted a number of comparative studies between ostriches and adult roosters with respect to true and apparent metabolisable energy, as well as the true and apparent availability of amino acids for certain feed ingredients. Cilliers *et al.* (1994) also conducted studies to determine requirements for growing ostriches that resulted in some basic recommendations for ostrich diets (Table 1).

Table 1. Practical diet specifications for ostriches in various stages of production (from Cilliers *et al.*, 1994)

	TME_n MJ/kg DM	PROTEIN g/kg DM	LYS g/kg DM	METH g/kg DM	TSAA* g/kg DM	ARG g/kg DM	THR g/kg DM	ILE g/kg DM	LEU g/kg DM
MAINTENANCE DIET	8.0	85.0	6.3	2.0	3.5	6.1	3.8	5.4	8.4
LAYER DIET	9.2	140	6.8	3.2	5.3	7.0	5.3	5.1	8.8

*TSAA - total sulphur amino acids

Since the energy values of raw materials for the compilation of ostriches feeds are limited, Brand *et al.* (2000a) compared the ME values for ostriches fed a range of balanced diets with different fibre and energy contents, with energy values obtained from pigs, poultry and ruminants. Table 1 was used as a background for the formulation of the diets tested. The results demonstrated the ability of ostriches to digest fibre better than other animals. Further studies by Salih *et al.* (1998) and Brand *et al.* (2000b) indicated that feeding young ostriches on low energy diets had no effect on their growth rate. Lower energy diets consequently can be used when growing/finishing ostriches to slaughter age with no adverse effects on production but with obvious financial implications.

Inadequate food or low quality food is most likely to be one contributing factor for the poor breeding results obtained in the past. The main reason seems to be ignorance with regard to the feed requirements during the breeding season in particular, since few studies have considered the nutritional requirements of breeding birds. Producers normally supply breeding birds with diets high in energy and protein to elevate production. These diets have led to obesity in ostriches. Based on information from other species, it is well known that obese breeders have lower rates of egg production, and lower fertility in both in males and females (Angel 1993). Hatchability of eggs produced by obese poultry breeders is also depressed. In other species, like horses, cattle and hogs, fertility, conception and birth rates are also decreased. The effects are more severe at high environmental temperatures. Soley *et al.* (1999) also confirmed that obesity in male ostriches leads to a reduction in fertility.

BACKGROUND TO THIS STUDY

Although ostrich farming is a well-established industry in South Africa, knowledge of nutritional requirements is not well defined. To ensure the industry's continued economic well being, ostrich research needs to pay particular attention to production techniques that will help to improve efficiency and result in better quality and profitability of ostrich products. Feeding costs represent a major capital input, currently comprising about 80% of the total cost of any intensive animal production system. In 1997 a sharp drop in ostrich prices plunged many ostrich farmers into financial difficulties. In times of economic hardship it is necessary to find alternative cost-effective diets for breeders without compromising egg-production, fertility and hatchability. The most expensive components of dietary formulations are protein and energy. Considering the effects of protein and energy supplementation on reproduction in breeding birds and the current obesity problems in ostriches thought to result from overfeeding of these components, this thesis aims to document feeding trials carried out over two consecutive breeding seasons to determine the effects on reproduction of different protein and energy levels in the diets of breeding ostriches. The objective is to reduce production costs by determining the minimum levels of protein and energy requirements needed to maintain high egg production, with good egg quality, high fertility, high hatchability, and high chick survival without compromising the condition of the breeding birds.

The thesis is divided into four main chapters. The first two of these assess the effect of different dietary protein and energy levels on production parameters and body condition of breeding female and male ostriches. Chapter 4 considers the effects of the different diets on egg quality and composition, and Chapter 5 assesses the effect of the nutritional regime in the previous year breeding season on production of the next year. The concluding chapter attempts to summarise the results and to make broad recommendations regarding dietary protein and energy composition suitable for breeding birds. The individual chapters have been written for publication with my superiors as co-authors. This has inevitably resulted in some unavoidable repetition, especially of parts of the introductions to the respective chapters, the methods and references.

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CHAPTER 2

THE EFFECT OF DIETARY ENERGY AND PROTEIN LEVELS ON PRODUCTION IN BREEDING FEMALE OSTRICHES

ABSTRACT

In a study that lasted over two breeding seasons, I assessed the effect of different energy and protein levels on body mass and body condition of, and egg production by, female ostriches. During the first breeding season, groups were fed diets with energy levels of 8.5, 9.5 and 10.5 MJ/kg dry mass (DM) metabolisable energy (ME) and protein levels of 13.5, 15 and 16.5%. Corresponding lysine levels were 0.65, 0.75 and 0.85%. In the second breeding season, groups were fed diets with levels of 7.5, 8.5 and 9.5 MJ/kg ME and protein levels of 10.5, 12 and 13.5%. Corresponding lysine levels were 0.49, 0.59 and 0.69%. Body mass of birds on diets of 7.5 and 8.5 MJ/kg ME decreased significantly compared with birds fed diets with higher energy levels and body measurements decreased, suggesting a loss of body condition. The females fed diets containing only 7.5 MJ/kg ME produced significantly fewer eggs at significantly longer intervals, resulting in fewer chicks hatched. No difference was found in egg mass, initial chick mass, chick survival till one month of age and body mass of chicks at one month. Different levels of dietary protein had no effect on egg production, egg mass, hatchability, initial chick mass, chick survival or chick mass at one month old. The female birds regained their original body mass during the four-month rest period, but significant differences in some parameters during the second breeding season suggest that they may not have fully recovered their body condition. A dietary energy level of 7.5 MJ/kg proved to have a negative effect on egg production by breeding female ostriches, and it may be concluded from this study, that a diet containing 8.5 MJ ME / kg DM and 10.5% protein should be regarded as a minimum.

INTRODUCTION

Adequate and appropriate nutrition is essential for the production of high quality commercially farmed animal species. South Africa has had a thriving ostrich industry for over a century. Despite this, our knowledge of the nutritional needs of ostriches is scant. The industry has consequently relied heavily on data derived from poultry, a practice that has recently been criticised (Cilliers & Angel, 1999). Egg production in breeding female birds is costly, both in terms of energy and specific nutrients, but whether egg production is limited by energy, protein or specific nutrients seems to differ in different birds (see, for example, Bolton *et al.* 1992, Williams 1996, Nager *et al.* 1997, Ramsey and Houston 1997). A scarcity of nutritional data specific to breeding ostriches has been suggested to be the main reason for poor egg production in some cases during the breeding season. The specification for ostrich feeds, in the Farm Feeds Act of 1947, is a minimum of 12% protein for *ad libitum* feeding and 13% for restricted feeding. The current trend, however, is to feed breeding ostriches high energy and protein level diets in an attempt to increase productivity. This practice does not necessarily always have beneficial effects on egg production in birds. Rosebrough *et al.* (1983) found that energy and protein utilisation for egg production in large white turkeys was better in birds fed lower protein and energy diets. Scott *et al.* (1999) found that feeding laying hens diets containing protein levels between 16 and 19% had no significant effect on egg production. Similarly, Goerzen *et al.* (1996) reported no difference in egg production between hens fed *ad libitum* and those on a restricted diet. Malden *et al.* (1979) indicated that if broiler breeders were allowed to get too fat, egg production would be depressed during the laying period. The use of energy values derived from poultry when formulating diets for breeding ostriches has led to obesity in breeding birds (Cilliers and Angel 1999). This may similarly affect breeding performance (Angel 1993). Badley (1997) suggested that excess fat deposits in some hens could prevent eggs from being deposited in the oviduct.

Energy and protein are the most expensive constituents of commercial animal feeds and the above information indicates that high levels of these in ostrich feeds may not be necessary. Studies by Salih *et al.* (1998) and Brand *et al.* (2000a), for example, indicate that feeding young ostriches lower-energy diets had no effect on their growth rate. Lower-energy diets consequently can be used when growing/finishing ostriches to slaughter age with no adverse effects on production, but with obvious financial implications (Brand *et al.* 2000b). Ostriches have an enhanced digestive capacity compared with poultry and some other domestic stock (Cilliers 1994, Brand *et al.* 2000), and Skadhauge *et al.* (1984) reported that ostriches could feed on lower quality fibrous plants because of the well-developed caecae and colon. The hindgut of ostriches is also adapted for hemicellulose and cellulose fermentation, and the production of volatile fatty acids in the hindgut can provide between 12% and 76% of the daily intake of metabolisable energy in growing ostriches (Swart 1988) and presumably also in adults. High levels of dietary protein also appear unnecessary for ostriches. The growth rate and food consumption of growing ostriches (60 – 110 kg) fed a 14% protein diet was better than that of birds fed higher protein level diets (Swart and Kemm 1985).

While there appears to be some evidence that growing ostriches can be fed low-energy and low-protein diets without adversely affecting their growth, it is not known what effects such diets may have on breeding birds. In females, especially, the demands for energy, protein and specific nutrients for egg formation may be high. Inadequate provision of these in the diet may lead to fewer small, poor quality eggs and, consequently, poor quality hatchlings with reduced fitness (Williams 1994, Deeming *et al.* 1996). At the same time, in the present economic climate, it is necessary to find cost-effective diets for breeding birds without compromising egg production and hatchability. In this study, I assessed the effects of dietary energy and protein levels on the body condition and productivity of breeding female ostriches.

MATERIALS AND METHODS

Experimental birds used in the study were African black ostriches from the commercial ostrich breeding flock at the Little Karoo Agricultural Development Centre near Oudtshoorn, South Africa. The management of the breeding flock was described by Van Schalkwyk *et al.* (1996), and the collection, subsequent treatment and incubation of the eggs by Van Schalkwyk *et al.* (1998).

The trial ran over two breeding seasons (1998/1999 and 1999/2000). Ninety pairs of adult breeding ostriches were divided randomly into nine groups of ten pairs/group during each experimental year. Groups therefore comprised different breeding pairs during each successive breeding season. Each breeding pair was kept in its own, separate breeding pen throughout the breeding season. During the first breeding season groups were fed diets with energy levels of 8.5, 9.5 and 10.5 MJ/kg dry mass (DM) metabolisable energy (ME) and protein levels of 13.5, 15 and 16.5%. Corresponding lysine levels were 0.65, 0.75 and 0.85%. The ninety pairs of breeders were again randomly divided for the second season and the groups were fed diets with energy levels of 7.5, 8.5 and 9.5 MJ/kg ME and protein levels of 10.5, 12 and 13.5%. Corresponding lysine levels were 0.49, 0.59 and 0.69%. Diet formulations (Tables 1 and 2) were done according to requirements and values for raw

Table 1. Composition of the nine experimental diets (kg/ton) fed to breeding birds during the first breeding season (1998).

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8	Diet 9
Lucerne meal	605.5	605.5	605.5	605.5	605.5	605.5	605.5	605.5	605.5
Oatbran	255.0	239.0	239.0	127.5	119.5	111.5	0.0	0.0	0.0
Maize meal	0.0	0.0	0.0	100.0	100.0	100.0	200.0	200.0	200.0
Soybean oilcake	11.2	64.6	64.6	5.6	57.9	110.2	0.0	51.2	102.3
Barley	78.2	39.1	39.1	111.2	66.2	21.3	144.1	93.3	42.5
Dicalcium phosphate	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Limestone	7.5	5.8	5.8	8.6	7.8	7.0	9.8	9.8	9.8
Monocalcium phosphate	13.9	17.0	17.0	13.3	14.5	15.7	12.6	12.0	11.3
Salt	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Min & Vit Premix	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Synthetic lysine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Synthetic methionine	1.7	2.0	2.0	1.4	1.7	2.0	1.0	1.3	1.6
TOTAL	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0
Composition (calculated)									
ME MJ/kg	8.50	8.50	8.50	9.50	9.50	9.50	10.50	10.50	10.50
Protein, %*	13.50	15.00	16.50	13.50	15.00	16.50	13.50	15.00	16.50
Lysine, %	0.65	0.75	0.85	0.65	0.75	0.85	0.65	0.75	0.85
Met-Sys, %	0.45	0.53	0.61	0.45	0.53	0.61	0.45	0.53	0.61
Tryptophan, %	0.25	0.29	0.32	0.26	0.29	0.33	0.26	0.30	0.33
Threonine, %	0.48	0.57	0.65	0.51	0.59	0.67	0.53	0.61	0.68
Crude fibre, %	25.6	25.07	24.53	22.55	22.33	22.12	19.50	19.60	19.70
Fat, %	1.40	1.35	1.30	1.71	1.65	1.59	2.02	1.95	1.87
Calcium, %	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Phosphorus,%	0.80	0.88	0.96	0.80	0.84	0.88	0.80	0.80	0.80

*Analysed

Table 2. Composition of the nine experimental diets (kg/ton) fed to breeding birds during the second breeding season (1999).

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8	Diet 9
Lucerne meal	138.6	69.3	0.0	280.5	216.7	152.9	422.3	364.0	305.7
Oatbran	700.0	701.7	703.3	486.6	502.7	518.8	273.2	303.8	334.3
Maize meal	14.0	7.0	0.0	130.8	108.5	86.2	247.6	210.0	172.4
Soybean oilcake	81.5	91.7	102.0	40.8	78.0	115.2	0.0	64.2	128.4
Cottonseed oilcake	0.0	59.6	119.2	0.0	29.8	59.6	0.0	0.0	0.0
Dicalcium phosphate	39.9	37.4	34.8	39.6	37.6	35.7	39.3	37.9	36.5
Limestone	13.9	20.8	27.7	10.3	15.1	19.9	6.6	9.3	12.0
Salt	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Min & Vit Premix	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Synthetic lysine	1.3	1.6	1.8	1.2	1.1	0.9	1.1	0.6	0.0
Synthetic methionine	1.8	2.0	2.2	1.3	1.6	2.0	0.9	1.3	1.7
TOTAL	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0
Composition (calculated)									
ME MJ/kg	7.50	7.50	7.50	8.50	8.50	8.50	9.50	9.50	9.50
Protein, %*	10.50	12.00	13.50	10.50	12.00	13.50	10.50	12.00	13.50
Lysine, %*	0.54	0.57	0.61	0.54	0.54	0.61	0.54	0.57	0.61
Met-Sys, %	0.37	0.46	0.54	0.37	0.45	0.54	0.37	0.45	0.54
Tryptophan, %	0.12	0.13	0.14	0.16	0.17	0.19	0.19	0.21	0.23
Threonine, %*	0.33	0.35	0.38	0.33	0.35	0.48	0.33	0.35	0.38
Crude fibre, %	23.55	22.26	20.96	22.04	21.10	20.17	20.53	19.95	19.37
Fat, %*	1.66	1.92	1.84	1.66	1.73	1.84	2.14	2.12	1.84
Calcium, %*	1.55	1.51	1.95	1.86	1.83	1.99	1.79	1.88	1.72
Phosphorus,%*	0.93	0.87	1.13	0.98	1.04	1.06	1.03	1.05	1.02

*Analysed

materials composition presented in the Elsenburg Ostrich Feed Database (Brand 2000). During both the first and the second season, the diets were analysed according to the AOAC methods (AOAC, 1984) to determine protein and lysine levels. The diets of the second season were analysed further to determine the threonine, fat, calcium and phosphorus contents. The feed was milled to pass through a 3-mm sieve and pelleted. The breeding birds were fed three times a week and each bird was given 2.5 kg DM/day throughout the breeding season (June – January). Between 8 and 15 fresh eggs per group of 30 birds were collected during the last month of the second breeding season for chemical analysis. This was taken into consideration in the calculation of the production and hatchability data. Ostriches deposit fat in a sub-peritoneal and subcutaneous layer over the sternum and ribs (Deeming *et al.* 1996), and measurements of thoracic and abdominal girth, in conjunction with body mass, can provide an indication of body condition. The body mass, thoracic girth, abdominal girth and tail circumference of the female ostriches were consequently measured at the beginning and end of the breeding season. Eggs were weighted immediately after collection but not subsequently during incubation. Laying interval, egg production and fate of eggs set in the incubator were recorded throughout the breeding season, as was the mass of successfully hatched chicks at four weeks of age. Data were analysed according to 3 energy x 3 protein factorial design with energy and protein levels as main factors (Statgraphics 1991). As is common practice on South African farms, females were separated from the males after the breeding season for a four-month rest period. During this period (February – May), the birds were fed a maintenance diet (Table 3). In the first rest period the body mass of females was determined monthly to monitor changes, but body mass was determined only at the beginning and end of the second rest period.

Table 3. Composition of the diet fed to females during the off-seasons (kg/ton).

Ingredients	Diet
Lucerne	580.6
Oatbran	138.1
Barley	249.0
Limestone	25.0
Salt	5.0
Min & Vit. Premix	2.0
Synthetic methionine	0.4
TOTAL	1000.0
Composition: (calculated)	
ME MJ/kg	9.1
Protein, %	13.3
Lysine, %	0.63
Met-Sys, %	0.35
Methionine, %	0.20
Threonine, %	0.50
Tryptophan, %	0.30

RESULTS

No significant interactions were observed between energy and protein levels ($P > 0.70$). The main effects of the different energy and protein levels in the diet are consequently presented separately.

Mean body mass of female ostriches assigned to the different dietary energy levels at the beginning of the first breeding season averaged between 111 and 115 kg and did not differ significantly between the different experimental groups ($P > 0.70$; Table 4). At the end of the breeding season, however, females fed the diet containing 8.5 MJ/kg ME had lost 8.5 kg body mass, those fed the 9.5 MJ/kg ME diet had not changed and those fed the 10.5 MJ/kg ME diet had gained 5 kg body mass. The body mass of birds fed the low-energy diet was significantly less ($P = 0.001$) than that of females fed the higher-energy diets (Table 4). At the beginning of the first breeding season there was no difference in the mean thoracic girth of females fed the different diets ($P > 0.05$; Table 4). At the end of the season the thoracic girth of birds on the 8.5 MJ/kg ME diet had decreased and was significantly smaller ($P = 0.001$) than that of birds fed the higher energy diets; in the latter groups the thoracic girth had increased by 2.8 and 3.1 cm respectively. In contrast, abdominal girth and tail circumference did not differ significantly for the various groups at the beginning of the season and both measurements decreased in all birds, with the largest decrease being shown by those birds fed the 8.5 MJ/kg ME diet. By the end of the breeding season these measured significantly less than in birds fed the higher-energy diets (Table 4). Although the body mass of females fed the 8.5 MJ/kg ME diet was significantly less at the end of the breeding season than that of females fed higher-energy diets, their body mass increased on the maintenance diet during the rest period and by the third month of the rest period their mean mass was indistinguishable from that of the other females (Table 4).

Mean body mass of females at the onset of the second breeding season averaged between 116 and 119 kg and did not differ significantly (Table 4). The body mass of all females decreased over the course of the second breeding season, with those birds fed the diet containing 7.5 MJ/kg ME losing 24.5 kg and those fed diets with 8.5 and 9.5 MJ/kg losing an average of 12 kg. The body mass of birds on the lowest energy diet was significantly lower ($P = 0.001$) at the end of the breeding season than that of the females fed diets of 8.5 and 9.5 MJ/kg (Table 4). There were no significant differences in the thoracic girth of birds on the

Table 4. The effect of dietary energy level on live body mass, body measurements and production of female ostriches over two seasons. (Mean ± SE)

Production parameters	Energy level (MJ/kg) first season (1998)			Significance Level (P)	Energy level (MJ/kg) second season (1999)			Significance Level (P)
	8.5	9.5	10.5		7.5	8.5	9.5	
Number of breeding pairs, n	30	30	30		30	30	30	
Starting mass, kg	111.3 ± 2.9	114.7 ± 2.9	112.8 ± 2.9	0.705	118.4 ± 2.8	115.8 ± 2.8	119.2 ± 2.7	0.659
End mass, kg	102.7 ± 2.5^{a}	114.6 ± 2.5^{b}	117.9 ± 2.5^{b}	0.001	93.9 ± 2.6^{a}	102.2 ± 2.5^{b}	105.0 ± 2.5^{b}	0.007
Mass change, kg	-8.5 ± 2.8^{a}	-0.1 ± 2.8^{b}	5.1 ± 2.8^{b}	0.003	-24.5 ± 2.0^{a}	-12.4 ± 2.0^{b}	-11.9 ± 2.0^{b}	0.001
Thoracic girth, cm								
Start of breeding season	118.6 ± 0.8	118.8 ± 0.8	121.1 ± 0.8	0.064	123.0 ± 1.1	124.2 ± 1.1	123.7 ± 1.1	0.735
End of breeding season	117.3 ± 1.1^{a}	121.6 ± 1.1^{b}	124.2 ± 1.1^{b}	0.001	114.2 ± 1.1^{a}	117.0 ± 1.0^{ab}	118.4 ± 1.0^{b}	0.021
Abdominal girth, cm								
Start of breeding season	145.3 ± 1.6	145.8 ± 1.6	147.5 ± 1.6	0.619	141.4 ± 1.3^{a}	142.9 ± 1.3^{ab}	145.6 ± 1.3^{b}	0.080
End of breeding season	137.4 ± 1.6^{a}	143.9 ± 1.6^{b}	143.5 ± 1.6^{b}	0.007	133.7 ± 1.5^{a}	128.3 ± 1.5^{b}	135.6 ± 1.5^{b}	0.002
Tail circumference, cm								
Start of breeding season	105.5 ± 1.3	106.4 ± 1.3	106.2 ± 1.3	0.897	95.2 ± 1.6^{a}	100.9 ± 1.6^{b}	101.5 ± 1.6^{b}	0.009
End of breeding season	100.3 ± 1.1^{a}	103.3 ± 1.1^{ab}	104.4 ± 1.1^{b}	0.042	95.9 ± 1.4^{a}	99.4 ± 1.3^{ab}	101.3 ± 1.3^{b}	0.023
Rest period								
Rest period starting mass, kg	102.7 ± 2.5^{a}	114.6 ± 2.5^{b}	117.9 ± 2.5^{b}	0.001	93.9 ± 2.6^{a}	102.2 ± 2.5^{b}	105.0 ± 2.5^{b}	0.007
Rest period, first month, kg	106.7 ± 2.8^{a}	110.9 ± 2.8^{ab}	117.9 ± 2.8^{b}	0.019	-	-	-	-
Rest period, second month, kg	118.1 ± 2.8^{a}	126.4 ± 2.9^{b}	127.4 ± 2.8^{b}	0.044	-	-	-	-
Rest period, third month, kg	119.4 ± 2.8	125.7 ± 2.9	127.6 ± 2.8	0.106	-	-	-	-
Rest period, fourth month, kg	112.8 ± 2.7	117.5 ± 2.9	120.9 ± 2.8	0.108	113.1± 2.9	117.6± 3.9	113.6± 3.2	0.650
Production								
Egg production, n	50.3 ± 4.2	53.9 ± 4.2	43.7 ± 4.1	0.215	36.0 ± 4.0^{a}	51.1 ± 3.9^{b}	54.0 ± 3.8^{b}	0.037
Laying interval, days	5.9 ± 0.7	5.1 ± 0.7	6.7 ± 0.7	0.303	11.5 ± 1.4^{a}	6.9 ± 1.4^{b}	7.4 ± 1.4^{b}	0.042
Live chicks hatched, %	62.9 ± 4.6	59.5 ± 4.7	66.9 ± 4.4	0.507	54.9 ± 4.5	45.3 ± 4.3	57.2 ± 4.3	0. 124
Hatchling mass, g	881 ± 15.2	891 ± 16.2	897 ± 15.2	0.753	872 ± 15.8	831 ± 15.3	865 ± 15.3	0.150
Number of chicks per hen at 1 month, n	12.7 ± 2.0	13.5 ± 2.0	13.1 ± 2.0	0.956	8.4 ± 1.6	10.3 ± 1.5	12.6 ± 1.5	0.167
Month-old mass, kg	3.3 ± 0.1	3.2 ± 0.1	3.4 ± 0.1	0.684	2.0 ± 0.1	2.0 ± 0.1	1.9 ± 0.1	0.748
Egg mass								
Initial mass, g	1473.2 ± 20.1	1475.5 ± 20.6	1477.6 ± 20.2	0.982	1429.6 ± 19.8	1409.3 ± 19.3	1459.4 ± 19.1	0.186

^{a,b} Denote significant ($P \leq 0.05$) difference between rows.

different diets at the beginning of the second season. Thoracic girth of birds in all groups decreased over the course of the season, with the biggest decrease (8.8cm) being measured in the birds fed the lowest energy diet and the smallest decrease (5.3cm) in birds fed the highest energy diet. The difference in thoracic girth at the end of the season was significant ($P < 0.02$) in birds fed the 7.5 and 9.5 MJ/kg ME diets. In contrast to thoracic girth, abdominal girth and tail circumference differed significantly in experimental groups at the onset of the second breeding season, with abdominal girth and tail circumference of the group assigned to the low-energy diet significantly smaller compared with the group assigned to the highest energy diet and to both groups assigned to the higher energy diets (Table 4). Abdominal girth decreased in all experimental groups by between 8 and 15 cm and, at the end of the season, measured significantly less in birds fed the lowest energy diet compared with the other two groups. Tail circumference changed little in the birds but at the end of the season also measured significantly less in birds fed the lowest energy diet compared with the other two groups. As with the first breeding season, the body mass of all birds increased during the rest period, and by the end of the four-month period it was statistically indistinguishable for birds fed the various diets.

The number of eggs produced by females during the first breeding season averaged between 44 and 54 and there was no significant difference between groups fed different energy level diets ($P > 0.20$; Table 4). Similarly, there were no significant differences in eggs laid by the various groups, the laying interval, the number of chicks hatched, the number of chicks surviving to one month old and the body mass of chicks at one month (Table 4). Egg production in the second season ranged from 36 to 54 eggs/female. Birds fed the 7.5 MJ/kg ME diet had a significantly lower egg production than females fed 8.5 and 9.5 MJ/kg ME ($P < 0.05$) due to of a significantly longer laying interval ($P < 0.05$). There was, however, no difference in the mean mass of eggs laid by each group ($P > 0.10$). The percentage of chicks hatched was not affected significantly ($P > 0.10$) by diet and there was no significant difference in the body mass of chicks hatched, their survival to one month old or their body mass at one month old. The body mass of chicks at one month old was substantially lower than that of chicks hatched in the first breeding season. It is unlikely that the poor growth of chicks is related to female nutrition in the second breeding season because hatchling masses were similar to the previous year. The relatively low mass at one-month old is more likely to reflect generally poor growth of chicks in this particular year because chicks other than those from experimental birds were similarly affected.

Table 5. The effect of dietary protein level on live body mass, body measurements and production of female ostriches over two seasons. (Mean ± SE)

Production parameters	**Protein (%) first season (1998)**			**Significance Level (P)**	**Protein (%) second season (1999)**			**Significance Level (P)**
	13.5	**15**	**16.5**		**10.5**	**12**	**13.5**	
Number of breeding pairs, n	30	30	30		30	30	30	
Starting mass, kg	116.6 ± 2.9	111.4 ± 2.9	110.8 ± 2.9	0.312	119.8 ± 2.8	115.3 ± 2.8	118.3 ± 2.7	0.530
End mass, kg	114.4 ± 2.5	109.1 ± 2.5	111.8 ± 2.5	0.320	102.4 ± 2.6	98.6 ± 2.5	100.1 ± 2.4	0.575
Mass change, kg	-2.2 ± 2.8	-2.3 ± 2.8	1.0 ± 2.8	0.632	-16.4 ± 2.0	-14.5 ± 2.0	-17.9 ± 2.0	0.471
Thoracic girth, cm								
Start of breeding season	120.6 ± 0.8	119.7 ± 0.8	118.2 ± 0.8	0.126	123.4 ± 1.1	123.0 ± 1.1	124.5 ± 1.1	0.607
End of breeding season	121.1 ± 1.1	121.1 ± 1.1	120.9 ± 1.1	0.993	117.1 ± 1.0	115.1 ± 1.0	117.4 ± 1.1	0.242
Abdominal girth, cm								
Start of breeding season	146.5 ± 1.6	147.0 ± 1.6	145.1 ± 1.6	0.677	143.7 ± 1.3	142.4 ± 1.3	143.8 ± 1.3	0.692
End of breeding season	142.3 ± 1.6	141.3 ± 1.6	141.3 ± 1.6	0.862	133.6 ± 1.5	132.1 ± 1.5	132.0 ± 1.5	0.698
Tail circumference, cm								
Start of breeding season	106.9 ± 1.3	105.2 ± 1.3	106.0 ± 1.3	0.657	100.7 ± 1.6	96.5 ± 1.6	100.5 ± 1.6	0.117
End of breeding season	104.1 ± 1.1	101.2 ± 1.1	102.7 ± 1.1	0.196	99.1 ± 1.4	97.8 ± 1.4	99.8 ± 1.3	0.561
Rest period								
Rest period starting mass, kg	114.4 ± 2.5	109.1 ± 2.5	111.8 ± 2.5	0.320	102.4 ± 2.6	98.6 ± 2.5	100.1 ± 2.4	0.575
Rest period, first month, kg	115.4 ± 2.8	110.7 ± 2.8	109.4 ± 2.8	0.279	-	-	-	-
Rest period, second month, kg	123.1 ± 2.8	124.6 ± 2.8	124.2 ± 2.9	0.924	-	-	-	-
Rest period, third month, kg	126.7 ± 2.8	123.8 ± 2.8	122.2 ± 2.9	0.511	-	-	-	-
Rest period, fourth month, kg	119.4 ± 2.8	116.0 ± 2.7	115.7 ± 2.8	0.586	114.4 ± 2.9	115.8 ± 3.9	114.0 ± 3.1	0.938
Production								
Egg production, n	48.8 ± 4.2	47.7 ± 4.1	51.5 ± 4.2	0.800	49.7 ± 3.8	41.4 ± 3.9	50.0 ± 4.0	0.218
Laying interval, days	6.1 ± 0.7	5.6 ± 0.7	6.1 ± 0.7	0.889	7.9 ± 1.4	9.7 ± 1.4	8.3 ± 1.4	0.604
Live chicks hatched, %	62.5 ± 4.7	69.3 ± 4.5	57.5 ± 4.5	0.183	53.2 ± 4.3	47.4 ± 4.5	56.8 ± 4.4	0.321
Hatchling mass, g	892 ± 16.2	888 ± 15.3	889 ± 15.2	0.988	870 ± 15.8	847 ± 15.5	851 ± 15.1	0.560
Number of chicks per hen at 1 month, n	12.2 ± 2.0	14.6 ± 2.0	12.6 ± 2.0	0.659	11.3 ± 1.6	7.8 ± 1.5	12.2 ± 1.5	0.108
Month-old mass, kg	3.5 ± 0.1	3.3 ± 0.1	3.1 ± 0.1	0.113	2.1± 0.1	1.9 ± 0.1	2.0± 0.1	0.123
Egg mass								
Initial mass, g	1485.0 ± 20.6	1466.4 ± 20.2	1473.9 ± 20.2	0.811	1435.9 ± 19.8	1423.3 ± 19.4	1439.2 ± 19.0	0.830

[a,b] Denote significant ($P \leq 0.05$) difference between rows.

The body mass of females fed diets with different protein level averaged between 111 and 117 kg at the beginning of the first breeding season and their mean body mass did not differ significantly (P > 0.25; Table 5). By the end of the breeding season, females fed diets of 13.5 and 15% protein had lost about 2 kg and those fed diets of 16.5% protein had gained 1.0 kg in absolute terms, but the mean mass of the groups did not differ significantly (P > 0.25; Table 5). Experimental groups did not differ in mean thoracic girth and abdominal girth and tail circumference at the beginning of the season. Thoracic girth of birds on all protein level diets increased slightly in all groups, whereas abdominal girth and tail circumference decreased in all groups. There were, however, no significant differences in any measurements between groups at the end of the season (Table 5).
The body mass of all birds increased during the rest period and they began the second breeding period heavier than they had been at the start of the previous season. However, the mean body mass of groups assigned to different dietary levels of protein (P > 0.50; Table 5) did not differ significantly. Thoracic girth, abdominal girth and tail circumference also did not differ significantly in the various groups. During the second breeding season the body mass of all groups of birds decreased. Loss of body mass averaged between 14.5 and 18 kg, but there was no trend in respect of extent of such loss and the level of protein in the diet, and mean body mass did not differ significantly for the various groups at the end of the breeding season. Similarly, no significant differences in measurements were found in mean body mass, thoracic girth, abdominal girth or tail circumference at the end of the second breeding season due to protein levels, although measurements of thoracic girth and abdominal girth decreased substantially in all groups (Table 5). Again, the body mass of all birds increased during the post-breeding rest period.

Females fed different protein level diets produced a mean of between 48 and 52 eggs/female over the first breeding season and between 41 and 50 eggs/female for the second season, but egg production did not differ significantly in birds fed different protein level diets (P's > 0.20; Table 5). There was also no significant difference in the mean initial mass of eggs set (P > 0.50). The first breeding season was 221 days, which gives a mean laying interval ranging from 5.1 to 6.7 days. The second breeding season was 280 days and the laying interval ranged from 7.9 to 9.7 days. There was no significant difference between the various treatments. No significant difference was evident in the percentage of chicks hatched from eggs produced by birds fed different protein level diets (P > 0.1; Table 5). There were no significant differences in the hatching mass of chicks, their survival to one month old or their body mass at one month old.

DISCUSSION

Egg production in birds is costly in terms of energy and nutrients. The required energy and nutrients for egg formation may be derived from daily food intake or from stored reserves. Daily food intake is probably a more important source of nutrients for small birds than stored reserves, but is also likely to be important in birds that lay many eggs or in birds that continue to lay replacement eggs if eggs are removed (Carey 1996). This applies particularly to commercial species like poultry and ostriches, where the principal objective is to maximise egg or chick production. Provision of adequate and appropriate nutrition is therefore especially important in such species. If energy or nutrients are limiting, birds can compensate by reducing egg size or the number of eggs laid, or by increasing the laying interval and spreading the cost of egg formation over a longer period. Young breeder fowls fed diets containing different levels of protein, for example, laid similar sized eggs but those fed low-protein diets laid significantly fewer eggs (Lilburn *et al.*, 1987). In ostriches, egg production was not affected in birds fed diets containing between 8.5 and 10.5 MJ/kg ME, but birds fed diets with only 7.5 MJ/kg ME laid significantly fewer eggs at a laying interval almost twice that of birds fed higher energy diets. This resulted in fewer chicks hatched. Furthermore, the body mass of female ostriches fed diets with a low-energy content (7.5 and 8.5 MJ/kg ME) generally decreased and was significantly lower by the end of the season than that of birds fed diets with higher energy levels. They also showed decreases in thoracic and abdominal girth, suggesting a general loss of body condition. In contrast, different levels of dietary protein between 10.5 and 16.5% had little effect on egg production, laying interval, egg mass or hatchability, and although body mass of birds fed different protein level diets decreased and they lost body condition, body mass and measurements did not differ significantly at the end of the breeding season. These results indicate that in ostrich diets, as used at this stage, energy rather than protein is the main constraint on egg production. This is consistent with results of Lopez and Leeson (1995a), who found no difference in egg production between breeding fowls fed diets with protein levels between 10 and 16%, although birds fed the 10% protein diet were significantly lighter than those fed the 16% protein diet, which indicates a loss of body condition. Similarly, Nager *et al.* (1997) found that supplementary feeding with two different levels of protein did not affect egg size or clutch size of great tits (*Parus major*). These results are, however, contrary to several studies that indicate that protein is the main constraint on egg production in some species of birds. In lesser black-backed gulls (*Larus fuscus*), protein reserves, but not fat (energy) reserves, decline during egg formation and the level of protein reserves also determines the ability of birds to lay replacement eggs (Houston *et al.* 1983). In years of low food availability, clutch size is depressed by protein limitation but not by energy (Bolton *et al.*1992). Similarly, captive mallards fed protein-enriched diets laid more eggs at a faster rate than those fed low protein diets (Eldridge and Krapu 1988). Food supplementation experiments also suggest the greater significance of protein, rather than energy, in zebra finches (*Taeniopygia guttata*) and blue tits (*Parus caeruleus*), which laid larger eggs when their diets were supplemented with protein than when supplemented with fat (energy) (Williams 1996, Ramsey and Houston 1997).

Female nutrition, through egg size and constituents, can also affect hatchling size and fitness (Williams 1994, Carey 1996). Zebra finches, whose diets were supplemented with protein, laid large eggs with a greater proportion of yolk and albumen protein (Williams 1996). Egg mass and yolk content of broiler breeders also increased as dietary energy and protein increased (Spratt *et al.* 1987), and black-backed gulls whose diets were supplemented with fish (protein) not only showed an increase in clutch size, but also laid larger eggs that produced larger and heavier hatchlings (Bolton *et al.* 1992). In contrast, Lopez (1995b) and Brum (1996) found that different dietary levels of protein had no effect on offspring performance of broiler breeders. Chick mass, growth rate and mortality were used as indicators to measure offspring performance. In ostriches, different levels of dietary energy and protein, as used in this experiments, had no significant effects on the mean mass of eggs laid, the mean mass of hatchlings or their survival to one month old.

Although there were no significant differences in egg mass, chick mass and survival between birds fed different energy and protein level diets in the two successive breeding seasons, substantial differences were evident in the performance of breeding females for those seasons, even among birds fed the same diets in both seasons. The laying intervals of birds fed the 8.5 and 9.5 MJ/kg in the second season were longer ($P \leq 0.05$) by 1.0 and 2.3 days respectively. No significant difference occurred in egg mass, hatchling mass, month-old mass and chick survival. Although the mean mass of birds at the beginning of the second breeding season was slightly greater than at the beginning of the first season, thoracic girth, abdominal girth and tail circumference were generally slightly less, suggesting that the birds possibly had not accumulated adequate body reserves during the four-month rest period.

CONCLUSIONS

The energy content of ostrich diets, as used in this experiments, appears to be the main constraint on egg production during breeding. Birds fed low-energy diets laid fewer eggs at longer intervals compared with birds fed higher energy diets and lost more body condition over the course of the breeding season. Body mass of birds fed diets containing 9.5 and 10.5 MJ/kg ME generally increased, or decreased less. In contrast, different levels of dietary protein had no significant effects on experimental groups. It may be concluded from this study that a diet containing at least 8.5 MJ ME / kg DM and 10.5% protein are sufficient for female breeding ostriches. Future studies are necessary to find the minimal protein and accompanying amino acid requirement for ostrich breeders. In our study, the female birds regained their original live body mass within four months during the rest period, but body measurements suggested that they might not have been capable of fully recovering body reserves.

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CHAPTER 3

THE EFFECT OF DIETARY ENERGY AND PROTEIN LEVELS ON CONDITION AND PRODUCTION OF BREEDING MALE OSTRICHES

ABSTRACT

The breeding season is regarded as an energy-expensive period for birds. The trend on commercial ostrich farms is consequently to feed breeding ostriches diets containing high levels of energy and protein to improve their production performance. Studies of growing ostriches, however, suggest that they could possibly be fed diets higher in fibre and with lower energy and protein levels without compromising production. In a study that ran over two breeding seasons, I assessed the effect of lower dietary energy and protein levels on body mass, body condition and male ostriches' production of fertile eggs. During the first season, birds were fed diets with energy levels of 8.5, 9.5 or 10.5 MJ/kg dry mass (DM) metabolisable energy (ME), and 13.5, 15 or 16.5% protein. Corresponding lysine levels were 0.65, 0.75 and 0.85%. In the second breeding season, the groups were fed diets with energy levels of 7.5, 8.5 and 9.5 MJ/kg ME and protein levels of 10.5, 12 and 13.5%. Corresponding lysine levels were 0.49, 0.59 and 0.69%. During the first breeding season, the mass of all birds increased, but the mass of those fed the 8.5 MJ/kg ME diet was significantly lower at the end of the season ($P < 0.001$) than that of birds fed diets of 9.5 and 10.5 MJ/kg ME. Body measurements (thoracic girth, abdominal girth and tail circumference) of birds fed the higher-energy diets increased, suggesting fat deposition. In contrast, body measurements of birds fed the 8.5 MJ/kg diet decreased, suggesting that they lost condition. During the second season, the trend in the case of the 8.5 and 9.5 MJ/kg diets was the same as that in the previous season, but a significant decrease in mass occurred in birds fed the 7.5 MJ/kg diet. Body measurements of all birds decreased and there were no significant differences in respect of the various energy levels, suggesting a general loss of body condition. In contrast to energy levels, different protein levels in the diets had no significant effect on any parameters measured. There were no trends or significant differences in the production of fertile eggs with any of the experimental diets. I conclude from this study that a level of 8.5 MJ/kg DM ME and 10.5% protein in the diet of breeding male ostriches is sufficient if an increase in mass and body condition are the main criteria for adjusting rations.

INTRODUCTION

Successful intensive commercial farming of ostriches requires an adequate knowledge of the nutritional needs of the birds and of components used in diet formulations. Although South Africa has had a well-established ostrich industry for over a century, information on ostrich nutrition, in particular specific nutritional requirements at different stages of production, is still sparse. Nutritional information extrapolated from the poultry industry has been widely used but has often proved unsatisfactory for ostriches and has resulted in several nutrition-related problems, especially in young, growing ostriches. One of the trends has been to feed ostriches concentrated diets with high energy and protein levels to increase production. However, recent studies of the metabolisable energy of specific components of diet formulations and various balanced diets have indicated that ostriches have an enhanced digestive capacity compared with poultry and some other domestic stock (Cilliers 1994, Brand *et al.* 2000a). Studies by Salih *et al.* (1998) and Brand *et al.* (2000a), for example, indicate that feeding young ostriches low-energy diets has no effect on their growth rate. Lower-energy diets consequently can be used when growing/finishing ostriches to slaughter age with no adverse effects on production, but with obvious financial implications. Furthermore, the hindgut of ostriches is adapted for hemicellulose and cellulose fermentation. The production of volatile fatty acids in the hindgut can provide between 12% and 76% of the daily intake of metabolisable energy in growing ostriches (Swart 1988). High levels of dietary protein also appear unnecessary for ostriches. The growth rate and food consumption of growing ostriches (60 – 110 kg) fed a 14% protein diet was better than that of birds fed diets with higher levels of protein (Swart and Kemm 1985).

Ignorance of the specific nutritional needs of breeding ostriches is probably a major contributing factor in their historically poor breeding performance. The use of energy values derived from poultry for ostrich breeder diets has led to obesity in breeding ostriches (Cilliers and Angel 1999), which may affect breeding performance (Angel 1993). Overfeeding of breeding birds has also been implicated as a factor in the high proportion of infertile eggs laid. Hatchability also decreases in eggs laid by obese poultry breeders. In other species like horses, cattle and hogs, fertility or conception rates decrease and birth rates drop, and in both poultry and mammals the effect is more severe at high environmental temperatures. Breeding birds from the South African Agricultural Development Centre at Oudtshoorn that were fed *ad libitum* had a 24.5% incidence of infertile eggs, whereas birds restricted to 2 kg of breeder diet/bird/day had an incidence of only 11.5 % of infertile eggs (Smith *et al.* 1995). A complicating factor is that males and females in the same paddock are fed the same diet, which is rich in calcium for laying females but low in zinc, which is essential for male sperm production. Male birds can consequently consume excess food, which results in obese males, potentially with poor sperm quality. Soley *et al.* (1999) also confirms that obesity in males leads to decreased fertility. This was confirmed by Bramwell *et al.* (1996), who observed a significant negative effect of decreased dietary energy intake on sperm concentration and total live sperm per milliliter of ejaculate It has been shown that feeding requirements for male and female chicks differ (NRC 1994), and presumably there will also be differences between adult male and female ostriches. Robinson (1996) found that the benefits of controlling body mass in male broiler breeders early in the breeding season are evident much later at the end of the breeding period. Separate sex feeding has been initiated in the management of broiler breeder flocks and is associated with an increase of about 5% in overall hatchability of eggs (Whitehead 1989). This increase was brought about through an increase in the fertility of eggs since hatchability of fertile eggs was unaffected. Studies of growing birds suggest that there is a potential for ostriches to be fed diets higher in fibre and with lower energy and protein levels without compromising production. In this study, I assessed the effect of lower energy and protein levels on body mass, body condition and the production of fertile eggs by breeding male ostriches. This information is particularly valuable for commercial ostrich enterprises because the protein, energy and fibre contents of diet formulations impact heavily on the cost of artificial feeds and consequently on production costs.

MATERIALS AND METHODS

Experimental birds used in the study were African black ostriches from the commercial breeding flock at the Little Karoo Agricultural Development Centre near Oudtshoorn, South Africa. Van Schalkwyk et al. (1996) have previously described management of the breeding flock. The trials ran over two breeding seasons (1998/1999 and 1999/2000). Ninety pairs of adult breeding ostriches were randomly divided into nine groups of 10 pairs/group during each experimental year. Groups therefore had different breeding pairs during each successive breeding season. The breeding pairs were kept in separate breeding pens throughout the whole of the breeding season. During the first season, birds were fed diets with energy levels of 8.5, 9.5 or 10.5 MJ/kg dry mass (DM) metabolisable energy (ME) and protein levels of 13.5, 15 or 16.5%. Corresponding lysine levels were 0.65, 0.75 and 0.85%. The ninety pairs of breeders were again randomly divided for the second season and the groups were fed diets with energy levels of 7.5, 8.5 and 9.5 MJ/kg ME and protein levels of 10.5, 12 and 13.5%. Corresponding lysine levels were 0.49, 0.59 and 0.69%. Diet formulations (Tables 1 and 2) were done according to requirement and raw material composition values presented in the Elsenburg Ostrich Feed Databases (Brand 2000b). For both the first and the second season, the diets were analysed according to the AOAC methods (AOAC, 1984) to determine the true protein and lysine levels.

Table 1. Composition of the nine experimental diets (kg/ton) fed to breeding birds during the first breeding season (1998).

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8	Diet 9
Lucerne	605.5	605.5	605.5	605.5	605.6	605.5	605.5	605.5	605.5
Oatbran	255.0	239.0	239.0	127.5	119.5	111.5	0.0	0.0	0.0
Maize	0.0	0.0	0.0	100.0	100.0	100.0	200.0	200.0	200.0
Soybean oilcake	11.2	64.6	64.6	5.6	57.9	110.2	0.0	51.2	102.3
Barley	78.2	39.1	39.1	111.2	66.2	21.3	144.1	93.3	42.5
Dicalcium phosphate	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Limestone	7.5	5.8	5.8	8.6	7.8	7.0	9.8	9.8	9.8
Monocalcium phosphates	13.9	17.0	17.0	13.3	14.5	15.7	12.6	12.0	11.3
Salt	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Min &Vit. Premix	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Synthetic lysine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Synthetic methionine	1.7	2.0	2.0	1.4	1.7	2.0	1.0	1.3	1.6
TOTAL	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0
Composition (calculated)									
ME MJ/kg	8.50	8.50	8.50	9.50	9.50	9.50	10.50	10.50	10.50
Protein, %*	13.50	15.00	16.50	13.50	15.00	16.50	13.50	15.00	16.50
Lysine, %*	0.65	0.75	0.85	0.65	0.75	0.85	0.65	0.75	0.85
Met-Sys, %	0.45	0.53	0.61	0.45	0.53	0.61	0.45	0.53	0.61
Tryptophan, %	0.25	0.29	0.32	0.26	0.29	0.33	0.26	0.30	0.33
Threonine, %	0.48	0.57	0.65	0.51	0.59	0.67	0.53	0.61	0.68
Crude fibre, %	25.60	25.07	24.53	22.55	22.33	22.12	19.50	19.60	19.70
Fat, %	1.40	1.35	1.30	1.71	1.65	1.59	2.02	1.95	1.87
Calcium, %	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Phosphorus, %	0.80	0.88	0.96	0.80	0.84	0.88	0.80	0.80	0.80

*Analysed

The diets of the second season were analysed further to determine the threonine, fat, calcium and phosphorus contents. The feeds were milled to pass through a 3.0-mm sieve and pelleted. The formulations and composition of the diets are given in Tables 1 and 2. The breeding birds were fed three times/week and were given 2.5 kg DM/bird.day throughout the breeding season (June – January). Ostriches deposit fat in a sub-peritoneal and subcutaneous layer over the sternum and ribs (Deeming *et al.* 1996), and measurements of these in conjunction with body mass can provide an indication of body condition. The birds were consequently measured at the beginning and end of the breeding season. Measurements included the thoracic girth, measured just in front of the legs, the abdominal girth, measured just behind the legs, and the tail circumference around the tail area. As is common practice on ostrich farms in South Africa, breeding birds were separated after the breeding season for a four-month rest period. During this time they were fed a maintenance diet comprising 8.5 MJ/kg ME and 9.1% protein (Table 3) to avoid mass gain and excessive mass at the beginning of the following breeding season. The mass of the males was recorded at the end of the rest period to make sure no substantial increase in mass had occurred during this period. Data were analysed according to 3 energy x 3 protein factorial design with energy and protein levels as main factors (Statgraphics 1991).

Table 2. Composition of the nine experimental diets (kg/ton) fed to breeding birds during the second breeding season (1999).

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8	Diet 9
Lucerne meal	138.6	69.3	0.0	280.5	216.7	152.9	422.3	364.0	305.7
Oatbran	700.0	701.7	703.3	486.6	502.7	518.8	273.2	303.8	334.3
Maize meal	14.0	7.0	0.0	130.8	108.5	86.2	247.6	210.0	172.4
Soybean oilcake	81.5	91.7	102.0	40.8	78.0	115.2	0.0	64.2	128.4
Cottonseed oilcake	0.0	59.6	119.2	0.0	29.8	59.6	0.0	0.0	0.0
Dicalcium phosphate	39.9	37.4	34.8	39.6	37.6	35.7	39.3	37.9	36.5
Limestone	13.9	20.8	27.7	10.3	15.1	19.9	6.6	9.3	12.0
Salt	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Min & Vit Premix	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Synthetic lysine	1.3	1.6	1.8	1.2	1.1	0.9	1.1	0.6	0.0
Synthetic methionine	1.8	2.0	2.2	1.3	1.6	2.0	0.9	1.3	1.7
TOTAL	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0
Composition (calculated)									
ME MJ/kg	7.50	7.50	7.50	8.50	8.50	8.50	9.50	9.50	9.50
Protein, %*	10.50	12.00	13.50	10.50	12.00	13.50	10.50	12.00	13.50
Lysine, %*	0.54	0.57	0.61	0.54	0.54	0.61	0.54	0.57	0.61
Met-Sys, %	0.37	0.46	0.54	0.37	0.45	0.54	0.37	0.45	0.54
Tryptophan, %	0.12	0.13	0.14	0.16	0.17	0.19	0.19	0.21	0.23
Threonine, %*	0.33	0.35	0.38	0.33	0.35	0.48	0.33	0.35	0.38
Crude fibre, %	23.55	22.26	20.96	22.04	21.10	20.17	20.53	19.95	19.37
Fat, %*	1.66	1.92	1.84	1.66	1.73	1.84	2.14	2.12	1.84
Calcium, %*	1.55	1.51	1.95	1.86	1.83	1.99	1.79	1.88	1.72
Phosphorus,%*	0.93	0.87	1.13	0.98	1.04	1.06	1.03	1.05	1.02

*Analysed

Table 3. Composition of the diet (kg/ton) fed to males during the rest period.

Ingredients	Diet
Lucerne	112.8
Oatbran	567.2
Barley	287.6
Limestone	25.0
Salt	5.0
Min & Vit. Premix	2.0
Synthetic methionine	0.4
TOTAL	1000.0
Composition: (calculated)	
ME MJ/kg	8.5
Protein, %	9.1
Lysine, %	0.27
Met-Sys, %	0.21
Methionine, %	0.13
Threonine, %	0.22
Tryptophan, %	0.14

RESULTS

There were no significant interactions between energy and protein levels ($P > 0.18$). The main effects are consequently presented separately.

The effects of the different energy levels on production for both seasons are shown in Table 4. At the onset of the breeding season, the mean mass of birds was between 117 and 123 kg and did not differ significantly for the various groups. During the first breeding season (1998/9) birds gained between 4 and 15 kg body mass over the course of the breeding season, with those birds fed the lowest-energy diets experiencing the least increase in mass and those fed the highest-energy diet the most. At the end of the season, the body mass of those birds fed the 8.5 MJ/ kg ME diet was significantly less ($P \leq 0.001$) than that of birds fed diets containing 9.5 and 10.5 MJ/kg ME. At the beginning of the breeding season there were no significant differences in thoracic girth, abdominal girth and tail circumference for birds in the different treatment groups (Table 4). Thoracic girth, abdominal girth and tail circumference of male birds fed the diets containing 9.5 and 10.5 MJ/kg ME all increased over the breeding season. In contrast, measurements of those birds fed the diet containing 8.5 MJ/kg ME decreased and were significantly less than those of birds fed the higher-energy diets ($P < 0.05$). Taken in conjunction with the relatively small increase in body mass, this suggests that these birds did not accumulate fat during the breeding season. The mass of all birds decreased during the four-month rest period, and at the end of that period their body mass was back to pre-breeding season levels and there were no significant differences between groups ($P > 0.25$; Table 4).

Mean mass of birds at the start of the second breeding season trial (1999/2000) was between 117 and 123 kg and, again, there was no significant differences between groups ($P > 0.20$, Table 4). During the second breeding season, the body mass of birds fed the 8.5 and 9.5 MJ/kg diets increased on average 0.6 and 6.4 kg respectively, although the mean mass of both groups at the end of the season did not differ significantly. In contrast, the body mass of birds fed the diet containing 7.5 MJ/kg decreased by 12.5 kg and was significantly less at the end of the season than that of birds fed the higher-energy diets. All birds experienced a decrease in mean thoracic girth, abdominal girth and tail circumference during the second season (1999/2000), with measurements of birds fed the lower-energy diets generally decreasing more than those of birds fed the higher-energy diets. There was, however, no significant difference in mean measurements between the groups at the end of the breeding season (Table 4). Birds gained between 5.1 and 6.7 kg during the rest period, although the

Table 4. The effect of different dietary energy levels on the mass, body measurements and production of breeding male ostriches over two breeding seasons. (Mean ± SE)

Production parameters	Energy level (MJ/kg) first season (1998/9)			Significance Level (P)	Energy level (MJ/kg) second season (1999/2000)			Significance Level (P)
	8.5	9.5	10.5		7.5	8.5	9.5	
Number of animals, n	30	30	30		30	30	30	
Starting mass, kg	117.3 ± 2.5	123.0 ± 2.6	119.6 ± 2.5	0.304	122.9 ± 2.6	120.9 ± 2.5	116.9 ± 2.5	0.240
End mass, kg	121.2 ± 2.7^{a}	130.9 ± 2.7^{b}	134.4 ± 2.7^{b}	0.002	110.2 ± 2.8^{a}	121.6 ± 2.8^{b}	122.0 ± 2.7^{b}	0.055
Mass change, kg	3.9 ± 1.5^{a}	8.1 ± 1.5^{b}	14.9 ± 1.5^{c}	0.001	-12.5 ± 1.7^{a}	0.6 ± 1.7^{b}	6.4 ± 1.7^{c}	0.001
Thoracic girth, cm								
Start of breeding season	123.7 ± 1.0	122.9 ± 1.0	123.2 ± 1.0	0.845	127.2 ± 1.2	127.0 ± 1.1	125.1 ± 1.1	0.337
End of breeding season	121.5 ± 1.1^{a}	126.7 ± 1.2^{b}	129.4 ± 1.1^{b}	0.001	121.2 ± 1.4	123.9 ± 1.4	124.3 ± 1.4	0.256
Abdominal girth, cm								
Start of breeding season	144.3 ± 1.5	146.2 ± 1.5	146.5 ± 1.5	0.523	140.6 ± 3.3	136.2 ± 3.2	141.5 ± 3.2	0.463
End of breeding season	142.2 ± 1.6^{a}	147.8 ± 1.6^{b}	149.5 ± 1.6^{b}	0.003	129.1 ± 1.7	130.5 ± 1.7	132.0 ± 1.7	0.497
Tail circumference, cm								
Start of breeding season	109.7 ± 1.1	107.8 ± 1.1	109.2 ± 1.1	0.443	103.6 ± 1.3	107.1 ± 1.3	103.7 ± 1.3	0.101
End of breeding season	106.7 ± 1.5^{a}	110.8 ± 1.6^{ab}	112.3 ± 1.5^{b}	0.033	100.4 ± 1.5	101.1 ± 1.5	103.1 ± 1.5	0.430
Rest period								
Rest period starting mass, kg	121.2 ± 2.7^{a}	130.9 ± 2.7^{b}	134.4 ± 2.7^{b}	0.002	110.2 ± 2.8^{a}	121.6 ± 2.8^{b}	122.0 ± 2.7^{b}	0.055
Rest period, four months, kg	117.7 ± 2.7	122.8 ± 2.8	123.1 ± 2.7	0.286	115.6 ± 2.5^{a}	128.3 ± 3.2^{b}	127.1 ± 2.8^{b}	0.025
Production								
Infertile eggs, %	19.7 ± 5.7	27.0 ± 5.7	25.6 ± 5.6	0.623	20.6 ± 4.2	26.8 ± 4.0	15.5 ± 4.0	0.144

$^{a,b\,c}$ Denote significant ($P \leq 0.05$) difference between rows.

Table 5. The effect of different dietary protein levels on the mass, body measurements and production of breeding male ostriches over two breeding seasons. (Mean ± SE)

Production parameters	Protein (%) first season (1998/9)			Significance Level (P)	Protein (%) second season (1999/2000)			Significance Level (P)
	13.5	15	16.5		10.5	12	13.5	
Number of animal, n	30	30	30		30	30	30	
Starting mass, kg	121.5 ± 2.5	119.7 ± 2.6	118.5 ± 2.5	0.699	122.4 ± 2.6	120.9 ± 2.6	117.3 ± 2.5	0.354
End mass, kg	131.2 ± 2.9	126.5 ± 2.7	128.9 ± 2.7	0.468	119.6 ± 3.0	119.4 ± 2.7	114.8 ± 2.7	0.382
Mass change, kg	9.7 ± 1.5	6.7 ± 1.5	10.5 ± 1.5	0.171	-2.6 ± 1.7	-0.3 ± 1.6	-2.4 ± 1.7	0.531
Thoracic girth, cm								
Start of breeding season	123.9 ± .10	123.3 ± 1.0.	122.6 ± 1.0	0.640	128.3 ±1.2	125.0 ±1.1	126.0 ±1.1	0.112
End of breeding season	127.0 ± 1.1	125.3 ± 1.2	125.2 ± 1.1	0.472	123.6 ±1.5	124.6 ± 1.4	121.1 ± 1.4	0.188
Abdominal girth, cm								
Start of breeding season	145.8 ± 1.5	144.8 ± 1.5	146.4 ± 1.5	0.758	141.2 ± 3.3	142.0 ± 3.3	135.1 ± 3.2	0.256
End of breeding season	147.8 ± 1.6	145.5 ± 1.6	146.3 ± 1.6	0.592	130.9 ± 1.8	130.7 ± 1.6	129.9 ± 1.7	0.912
Tail circumference, cm								
Start of breeding season	109.5 ± 1.1	107.2 ± 1.1	110.2 ± 1.1	0.157	105.0 ± 1.3	105.1 ± 1.3	104.4 ± 1.3	0.910
End of breeding season	111.7 ± 1.5	108.6 ± 1.6	109.5 ± 1.5	0.333	102.4 ± 1.6	101.6 ± 1.4	100.6 ± 1.5	0.711
Rest period								
Rest period starting mass, kg	131.2 ± 2.9	126.5 ± 2.7	128.9 ± 2.7	0.468	118.7 ± 2.6	119.7 ± 2.7	114.3 ± 2.6	0.308
Rest period, four months, kg	121.0 ± 2.8	121.9 ± 2.7	120.7 ± 2.6	0.951	122.8 ± 2.9	124.9 ± 3.1	123.3 ± 2.5	0.880
Production								
Infertile eggs, %	29.4 ± 5.7	19.1 ± 5.6	23.8 ± 5.7	0.432	21.4 ± 4.0	22.3 ± 4.2	19.2 ± 4.1	0.864

[a,b,c] Denote significant ($P \leq 0.05$) difference between rows.

mass of birds fed the 7.5 MJ/kg diet during the breeding season was still significantly below that of the other birds at the end of the season and also below their own body mass at the start of the breeding season.

The proportion of infertile eggs over the two seasons ranged from approximately 8 to 27%. There were no evident trends in the proportion of fertile eggs in relation to dietary energy levels, and mean values did not differ significantly for the various treatment groups in any one season (Table 4). There was, however, a substantially lower proportion of infertile eggs in the second breeding season.

The effects of different protein levels on body mass and body measurements over the two breeding seasons are shown in Table 5. Again, the mass of birds assigned to different diets did not differ significantly at the onset of the breeding seasons. Males on the three different protein diets gained between 7 and 11 kg over the first breeding season but their mass at the end of the season did not differ significantly ($P = 0.468$). Thoracic and abdominal girth and tail circumference generally increased slightly (Table 5) but did not differ significantly for birds fed different diets. During the second breeding season, all birds experienced a decrease in mass. The decrease in mass ranged on average between 0.3 and 2.6 kg and final body mass in the various groups did not differ (Table 5). Thoracic and abdominal girth and tail circumference decreased, but again, at the end of the season, did not differ significantly for birds fed different diets. Males generally experienced a decrease in mass during the first rest period. At the end of the rest period their body mass corresponded closely with their mass at the start of the breeding season and there was no significant difference between birds fed diets containing different levels of protein (Table 5). In the rest period following the second breeding season, birds gained between 4 and 9 kg. The increase in mass corresponded with the proportion of protein in the diet but mass at the end did not differ significantly.

There were no significant differences in the production of fertile eggs for males fed different levels of dietary protein (Table 5), although there was a trend for fewer infertile eggs to be produced in the second season.

DISCUSSION AND CONCLUSION

Male ostriches fed high-energy diets (9.5 and 10.5 MJ/kg ME) generally experienced an increase in mass over the course of the breeding season. Their thoracic girth, abdominal girth and tail circumference also increased over the breeding season. This, combined with the increase in body mass, suggests that they were overfed and laid down fat deposits. The body

mass of birds fed a diet containing 8.5 MJ/kg ME was either slightly more or remained the same, and there were slight decreases in thoracic and abdominal girth and tail circumference. In contrast, birds fed a low-energy diet containing only 7.5 MJ/kg ME experienced a substantial decrease in mass and also in thoracic and abdominal girth and tail circumference. This decrease in body measurements, taken in conjunction with the more substantial decrease in body mass, suggests that these birds lost condition during the breeding season. Since most other domestic animal species are managed so as to bring about a decrease in mass during the breeding season, the dietary energy levels of 7.5 or 8.5 MJ/kg would seem to be the most desirable for breeding male ostriches.
Birds on all protein levels similarly experienced an increase in mass during the first breeding season, and although a slight decrease in mass occurred during the second season, it seems that protein levels ranging between 10.5% and 16.5% did not otherwise affect body mass or body measurements.

In a trial undertaken with male turkeys, Cecil (1982) found that the concentration of semen collected from males on different protein levels (8, 11, 13 and 17%) was consistent. Fertility and hatchability of eggs did not differ with the various treatments. Sexton (1986) and Dobrescru (1986) confirmed that low protein levels had no effect on fertility, as long as the males were in good reproductive condition at the onset of the breeding season. In our study, no significant difference in egg fertility was found between the different protein levels (Table 5). It may be concluded from this study that levels of 7.5 MJ ME/kg DM and 10.5% protein in the diet of breeding male ostriches are sufficient if an increase in body mass is the main criterion for adjusting rations.

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CHAPTER 4

THE EFFECT OF DIETARY ENERGY AND PROTEIN LEVELS ON THE COMPOSITION OF OSTRICH EGGS

ABSTRACT

Nutrition of breeding female birds can influence egg quality and is therefore extremely important for the development of the embryo and the successful hatching of a high quality chick. In this study the effect of different energy and protein levels in the diets of female ostriches on the composition of their eggs were determined. Ninety pairs of breeding ostriches were divided randomly into nine groups of ten pairs per group. The groups were fed diets with levels of 7.5, 8.5 and 9.5 MJ/kg ME and protein levels of 10.5, 12 and 13.5%. Fresh eggs were collected and the albumen and yolk separated and analysed for protein and lipid content and for amino acid and mineral composition. Despite some significant differences in composition and amino acid levels, different dietary energy levels, dietary protein and amino acid levels for the most part had little or no effect on the composition of ostrich eggs.

INTRODUCTION

Apart from physical factors like temperature, water vapour pressure gradients, and turning, bird embryos are entirely dependent upon the contents of the preformed egg for successful growth and development (Whitehead 1989). The yolk and albumen in the egg supply the developing embryo with nutrients and water for normal growth. Yolk is an important nutritional component of the avian egg because it yields 75% of the calories and provides all the lipids, and thus the energy, for the developing embryo (Noble *et al.* 1996). Yolk lipids also provide a range of essential components for tissue development and function, and the yolk all or most of the minerals, vitamin A and thiamine. The albumen is an important reservoir for water, essential ions and protein, the last-mentioned forming 99% of the dry matter of albumen and also having useful anti-microbial properties (Deeming 1997).

Egg composition varies between avian species depending on the stage of development of hatchlings on the altricial-precocial continuum. Within a specific species, however, the number of eggs produced and their size and composition are variables that are affected by several factors including the physical environment and the age, genetic background and nutrition of the hen (Badley 1997). The nutrition of the breeding female in particular can influence many of these characteristics and is therefore extremely important for the development of the embryo and the successful hatching of a high quality chick. Protein content of food, rather than energy, may be a limiting factor for egg formation in birds (Nager *et al.* 1997), but the role of dietary protein and energy levels in egg production and quality is equivocal.

Ostriches have been reared commercially in South Africa for over a century. After laying, eggs are removed for artificial incubation and the females continue to lay eggs at a rate of approximately one every 2-5 days throughout the breeding season (June – January). The average mass of an ostrich egg is 1455 g, which represents approximately 1.2% of the body mass of the adult female. This is similar to that of turkeys (approximately 1.0%) but considerably less than the 3.5% for poultry and the 8% for quail (Sales *et al.* 1996). Because commercially farmed ostriches have an extended breeding season during which individual females may lay up to 50 or more eggs, nutrition may play a particularly important role in egg production. Nutrient deficiencies in the egg at laying may ultimately result in embryonic mortality and reduced hatchability or in poor quality hatchlings. There have, however, been no reports of the effect of nutrition on egg quality and hatchability of ostrich eggs. I consequently assessed the influence of different dietary energy and protein levels on egg production and the composition of ostrich eggs.

MATERIALS AND METHODS

Experimental birds used in the study were African black ostriches from the commercial ostrich breeding flock at the Little Karoo Agricultural Development Centre near Oudtshoorn, South Africa. Management of the breeding flock and treatment of the eggs were described by Van Schalkwyk *et al.* (1996) and Van Schalkwyk *et al.* (1998). Ninety pairs of adult breeding ostriches were divided randomly into nine groups of ten pairs per group during each experimental year. Groups therefore had different breeding pairs during each successive breeding season. The breeding pairs were kept in separate breeding pens throughout the whole of the breeding season. The groups were fed diets with levels of 7.5, 8.5 and 9.5 MJ/kg metabolisable energy and protein levels of 10.5, 12 and 13.5%. Corresponding lysine levels were 0.49, 0.59 and 0.69. Diet formulations were done according to requirement and raw material composition values presented in the Elsenburg Ostrich Feed Databases (Brand 2000). Diets fed to the birds are described in Chapter 2. The feeds were milled to pass a 3-mm sieve and pelleted. The breeding birds were fed three times a week and each bird was given 2.5 kg DM/day throughout the breeding season (June – January).

During the last month of the breeding season (January), between 8 and 15 fresh eggs per group of 30 birds were collected from different breeding pairs within each group of 30 females fed each experimental diet. Number of eggs per treatment differs because some breeding pairs stopped production. All egg components were studied raw to avoid artefacts in their composition that might be caused by boiling. The mass of the eggs was determined for total egg mass, and the eggs were then frozen to make the separation of the yolk and albumen easier. After this, the eggs were broken to separate these components. The mass of the shell (including membranes), yolk and albumen was determined. The albumen and yolk were freeze-dried for 36 hours in a vacuum freeze-dryer to determine the dry mass. Protein content of albumen and yolk was determined using a Leco Nitrogen Analyser (Model FP 428) according to methods prescribed by the Association of Official Analytical Chemists (AOAC 1995). Fat was extracted in petroleum ether using the Soxhlet method (AOAC 1995). Ash content was determined following combustion at 500°C in a muffle furnace for eight hours. The amino acids were analysed using the APLC method (Einasson *et al.*1983). Minerals were analysed by the standard AOAC methods (AOAC, 1975). Data were analysed according to 3 energy x 3 protein factorial design with energy and protein levels featuring as main factors. For this, Statgraphics statistical software (Statgraphics, 1991) was used.

RESULTS

No significant interactions were observed between energy and protein levels. The main effects of the different energy and protein levels in the diet are consequently presented separately.

Physical characteristics of the eggs

Different levels of dietary energy and protein had no effect on the physical characteristics of the eggs. Overall, the mass of eggs ranged between 1347 and 1446 g and did not differ significantly for females fed diets with different energy or protein levels (P's > 0.50, Table 1). There was also no significant difference in the mass of the shell and membranes or wet albumen and yolk mass of the eggs (Table 1). Shell and membrane mass ranged from 276 to 295 g (approximately 20% of fresh egg mass), and albumen and yolk made up approximately 70% and 30% of the egg contents respectively.

Egg composition

Overall, water content comprised 47 - 48% of the yolk. Yolk water content in the case of females fed the low-energy diet averaged 47.0%, which was slightly, but significantly, lower than for females fed the higher-energy diets ($P < 0.01$; Table 2), but yolk water content was not influenced by different levels of dietary protein. Yolk lipid and crude protein averaged about 57 and 32% respectively and did not differ significantly for females fed the different diets (Table 2). Inorganic (ash) content of the yolks averaged between 3.8 and 4.2% and, although there were significant differences in the inorganic content of yolks from females fed diets with different energy levels ($P < 0.05$; Table 2), these differences did not relate to the different energy levels in any consistent way. Dietary protein had no significant effect on the inorganic content of the yolk.

Water content of ostrich egg albumen averaged 90% and was not significantly influenced by dietary energy or protein levels ($P > 0.75$; Table 2). Of the dry matter, about 76 – 78% was made up of protein, which was also not significantly influenced by dietary energy or protein levels ($P > 0.20$; Table 2). Lipid made up only between 0.09 and 0.30% of the albumen and was significantly lower in females fed the low-energy diet (0.09%) compared with those fed the high-energy diet ($P < 0.04$). Different dietary protein levels, however, had no effect on albumen lipid content ($P > 0.50$; Table 2).

Table 1. The effect of dietary energy and protein levels on the physical characteristics of ostrich eggs. (Mean ± SE)

Physical characteristics	**Energy level (MJ/kg)**			**Significance Level (P)**	**Protein (%)**			**Significance Level (P)**
	7.5	**8.5**	**9.5**		**10.5**	**12.0**	**13.5**	
Number of eggs, n	8	15	15		15	12	11	
Egg mass (g)	1446.0 ± 78.7	1357.8 ± 47.4	1380.0 ± 47.4	0.640	1409.6 ± 47.4	1346.8 ± 58.0	1427.4 ± 72.3	0.617
Shell + membrane mass (g)	289.8 ± 12.9	285.5 ± 7.7	281.2 ± 7.7	0.831	294.7 ± 7.7	275.6 ± 9.4	286.3 ± 11.7	0.301
Albumen mass (g)	810.6 ± 59.0	726.9 ± 35.1	730.3 ± 35.1	0.450	744.4 ± 35.1	729.2 ± 42.9	794.1 ± 53.6	0.630
Yolk mass (g)	329.3 ± 27.7	337.5 ± 16.5	342.3 ± 16.5	0.920	337.2 ± 16.5	335.8 ± 20.2	336.1 ± 25.2	0.998

Table 2. The effect of dietary energy and protein levels on the nutritional content of albumen and yolk of ostrich eggs. (Mean ± SE) (All constituents on a DM basis expect dry matter and moisture percentage)

Egg composition	**Energy level (MJ/kg)**			**Significance Level (P)**	**Protein (%)**			**Significance Level (P)**
	7.5	**8.5**	**9.5**		**10.5**	**12.0**	**13.5**	
Number of eggs, n	7	15	10		14	10	9	
YOLK								
Moisture, %	47.0 ± 0.3^{a}	48.2 ± 0.2^{b}	48.1 ± 0.3^{b}	0.009	47.8 ± 0.2	48.2 ± 0.3	47.3 ± 0.3	0.154
Dry matter, %	53.0 ± 0.3^{a}	51.8 ± 0.2^{b}	51.9 ± 0.^{b}	0.009	52.2 ± 0.2	51.8 ± 0.3	52.7 ± 0.3	0.153
Ash,%	3.8 ± 0.2^{ab}	4.2 ± 0.1^{a}	3.8 ± 0.2^{b}	0.043	4.0 ± 0.1	3.8 ± 0.2	4.0 ± 0.2	0.709
Crude protein, %	31.0 ± 0.6	32.2 ± 0.4	31.9 ± 0.6	0.327	31.9 ± 0.4	32.2 ± 0.6	30.9 ± 0.6	0.286
Lipid, %	57.9 ± 0.6	57.3 ± 0.3	57.3 ± 0.5	0.592	57.9 ± 0.3	57.1 ± 0.6	57.5 ± 0.5	0.464
ALBUMEN								
Moisture, %	90.0 ± 0.6	90.3 ± 0.4	89.8 ± 0.6	0.754	90.2 ± 0.4	89.7 ± 0.6	90.2 ± 0.6	0.777
Dry matter, %	10.0 ± 0.6	9.7 ± 0.4	10.2 ± 0.6	0.739	9.8 ± 0.4	10.3 ± 0.6	9.8 ± 0.6	0.785
Ash,%	7.1± 0.2	7.4 ± 0.1	6.9 ± 0.2	0.220	7.1 ± 0.1	7.1 ± 0.2	7.3 ± 0.2	0.842
Crude protein, %	76.4 ± 0.7	76.8 ± 0.4	78.0 ± 0.7	0.244	77.4 ± 0.4	76.8 ± 0.7	77.0 ± 0.7	0.781
Lipid, %	0.09 ± 0.07^{a}	0.30 ± 0.04^{b}	0.19 ± 0.06^{ab}	0.038	0.24 ± 0.04	0.16 ± 0.07	0.18 ± 0.06	0.554

[a,b] Denote significant ($P \leq 0.05$) difference in rows.

Table 3. The effect of dietary energy and protein levels on the amino acid content of the albumen of ostrich eggs. (Mean ± SE) (All constituents on a DM basis expect dry matter and moisture percentage)

Amino acid g/100 g	Energy (MJ/kg ME)			Significance Level (P)	Protein (%)			Significance Level (P)
	7.5	8.5	9.5		10.5	12	13.5	
Number of eggs, n	6	11	7		9	8	7	
Essential								
Methionine	0.63 ± 0.22	1.07 ± 0.15	0.95 ± 0.21	0.286	0.91 ± 0.16	0.77 ± 0.21	0.97 ± 0.21	0.795
Lysine	4.6 ± 0.10	4.4 ± 0.07	4.6 ± 0.09	0.122	4.6 ± 0.07	4.6 ± 0.09	4.5 ± 0.09	0.505
Arginine	2.1 ± 0.11^{a}	2.9 ± 0.8^{b}	3.2 ± 0.11^{c}	0.001	$2.7 \pm 0.^{ab}$	3.0 ± 0.1^{a}	2.5 ± 0.1^{b}	0.025
Threonine	3.4 ± 0.09^{ab}	3.3 ± 0.06^{a}	3.6 ± 0.09^{b}	0.030	3.3 ± 0.07	3.4 ± 0.09	3.5 ± 0.09	0.440
Valine	5.0 ± 0.06^{a}	4.8 ± 0.04^{b}	5.1 ± 0.05^{a}	0.001	4.9 ± 0.04	5.0 ± 0.06	4.9 ± 0.05	0.589
Phenylalanine	3.9 ± 0.05^{a}	3.9 ± 0.04^{a}	4.1 ± 0.05^{b}	0.008	3.9 ± 0.04	4.0 ± 0.5	4.0 ± 0.05	0.627
Isoleucine	4.4 ± 0.05^{a}	4.2 ± 0.04^{b}	4.5 ± 0.05^{a}	0.001	4.4 ± 0.04	4.4 ± 0.05	4.3 ± 0.05	0.609
Leucine	6.4 ± 0.07^{ab}	6.2 ± 0.05^{a}	6.6 ± 0.07^{b}	0.002	6.4 ± 0.05	6.4 ± 0.07	6.2 ± 0.07	0.122
Histidine	1.7 ± 0.23	1.5 ± 0.16	1.3 ± 0.22	0.359	1.5 ± 0.17	1.4 ± 0.22	1.5 ± 0.22	0.985
Non-essential								
Serine	4.0 ± 0.24	3.5 ± 0.16	4.0 ± 0.22	0.139	3.7 ± 0.17	3.8 ± 0.23	4.0 ± 0.22	0.609
Tyrosine	4.0 ± 0.18	4.0 ± 0.12	4.4 ± 0.17	0.121	4.2 ± 0.13	4.1 ± 0.17	4.1 ± 0.17	0.254
Acidic amino acids								
Aspargine	6.1 ± 0.12^{a}	5.7 ± 0.08^{b}	6.2 ± 0.11^{a}	0.006	6.0 ± 0.09	6.1 ± 0.11	5.9 ± 0.11	0.581
Glutamine	9.1 ± 0.12^{a}	8.8 ± 0.08^{b}	9.3 ± 0.11^{a}	0.006	9.1 ± 0.09	9.1 ± 0.12	9.0 ± 0.11	0.856
Aliphatic amino acids								
Glycine	2.5 ± 0.06^{a}	2.3 ± 0.04^{b}	2.4 ± 0.06^{ab}	0.109	2.4 ± 0.05	2.4 ± 0.06	2.4 ±0.06	0.824
Alanine	3.4 ± 0.09^{ab}	3.2 ± 0.06^{a}	3.5 ± 0.09^{b}	0.046	3.4 ± 0.07	3.3 ± 0.09	3.4 ± 0.09	0.845
Basic amino acids								
Proline	3.2 ± 0.07^{a}	2.9 ± 0.05^{b}	3.1 ± 0.6^{a}	0.006	3.1 ± 0.05	3.1 ± 0.06	3.0 ± 0.06	0.698
Hydroxyproline	0.04 ± 0.04	0.01 ± 0.02	0.01 ± 0.03	0.837	0.04 ± 0.03	0.00 ± 0.03	0.03 ± 0.03	0.591

^{a,b,c} Denote significant ($P < 0.05$) difference in rows.

Table 4. Mineral content of the yolk and albumen of ostrich eggs. (Mean ± SE) (All constituents on a DM basis expect dry matter and percentage moisture)

Minerals	Energy level (MJ/kg)			Significance Level (P)	Protein (%)			Significance Level (P)
	7.5	8.5	9.5		10.5	12	13.5	
Number of eggs, n	7	15	10		14	10	9	
YOLK								
P, %	0.75 ± 0.020	0.76 ± 0.011	0.74 ± 0.018	0.824	0.75 ± 0.012	0.76 ± 0.019	0.75 ±0.018	0.934
K, %	0.20 ± 0.012	0.21 ± 0.007	0.19 ± 0.011	0.198	0.20 ±0.007	0.19 ± 0.012	0.21 ± 0.011	0.653
Ca, %	0.23 ± 0.006	0.24 ± 0.004	0.23 ± 0.006	0.517	0.24 ± 0.004	0.24 ±0.006	0.23 ±0.006	0.512
Mg, %	0.24 ± 0.002	0.23 ± 0.001	0.21 ± 0.002	0.363	0.22 ± 0.001	0.25 ±0.002	0.20 ± 0.002	0.199
Na, mg/kg	1400.8 ± 79.2	1393.2 ± 43.4	1425.0 ± 73.2	0.933	1347.1 ± 47.1	1494.0 ± 77.1	1377.9 ± 73.2	0.282
Cu, mg/kg	0.95 ± 0.10^{a}	0.65 ± 0.05^{b}	0.67 ± 0.09^{b}	0.031	0.80 ± 0.06	0.87 ± 0.09	0.60 ± 0.09	0.090
Zn, mg/kg	44.4 ± 1.8	45.1 ± 1.0	42.0 ± 1.6	0.292	43.8 ± 1.1	45.8 ± 1.7	41.9 ± 4.6	0.263
Mn, mg/kg	0.98 ± 0.09	1.07 ± 0.05	1.00 ± 0.9	0.654	1.08 ± .06	1.00 ± 0.09	0.98 ± 0.09	0.571
Fe, mg/kg	65.8 ± 4.8	69.1 ± 2.6	70.9 ± 4.4	0.733	72.0 ± 2.8	69.9 ± 4.6	63.8 ± 4.4	0.313
ALBUMEN								
P, %	0.17 ± 0.007	0.16 ± 0.004	0.16 ± 0.006	0.968	0.15 ± 0.004^{a}	0.17 ± 0.007^{b}	0.17 ± 0.006^{b}	0.035
K, %	1.15 ± 0.10	1.2 ± 0.06	1.1 ± 0.09	0.802	1.2 ± 0.06	1.3 ± 0.10	1.1 ± 0.09	0.341
Ca, %	0.21 ± 0.07	0.31 ± 0.04	0.21 ± 0.07	0.319	0.21 ± 0.04	0.27 ± 0.07	0.24 ± 0.07	0.805
Mg, %	0.15 ± 0.006	0.15 ± 0.003	0.14 ± 0.005	0.532	0.15 ± 0.004	0.15 ± 0.006	0.15 ± 0.006	0.867
Na, mg/kg	19437.8 ± 1569.0	18852.7 ± 913.3	19188.7 ± 1428.2	0.943	20710.5 ± 956.3	17918.7 ± 1520.3	18850.0 ± 1452.7	0.263
Cu, mg/kg	7.5 ± 0.5	7.8 ± 0.3	7.2 ± 0.4	0.520	7.1 ± 0.3^{a}	8.3 ± 0.4^{ac}	7.0 ± 0.4^{ab}	0.084
Zn, mg/kg	2.8 ± 0.8	2.4 ± 0.4	2.8 ± 0.7	0.811	2.7 ± 0.5	3.0 ± 0.7	2.3 ± 0.7	0.781
Mn, mg/kg	2.1 ± 0.5	1.7 ± 0.3	1.6 ± 0.5	0.742	0.99 ± 0.3^{a}	2.1 ± 0.5^{ab}	2.2 ± 0.5^{b}	0.064
Fe, mg/kg	1.8 ± 1.6	4.9 ± 0.9	3.9 ± 1.4	0.251	4.9 ± 0.9	2.2 ± 1.5	3.6 ± 1.4	0.328

^{a,b} Denote significant ($P \leq 0.05$) difference in rows.

Amino acids

Amino acid concentrations in the albumen of ostrich eggs are shown in Table 3. Although concentrations of these were generally very similar in eggs from females fed different energy level diets, some of the differences were nevertheless statistically significant. The concentration of the essential amino acid arginine increased significantly with increasing energy content of the diet, and threonine, phenylalanine and leucine tended to be highest in eggs from birds fed the highest energy level diets. Although several of the other amino acids also differed significantly (Table 3), there was no consistent relationship between energy level in the diet and amino acid concentration in the albumen. Different concentrations of dietary protein had no significant effect on the concentrations of amino acids in the albumen of ostrich eggs except for arginine, which although significantly different for the different diets, showed no consistent pattern (Table 3).

Minerals

Mineral concentrations in the yolk and albumen of ostrich eggs are reflected in Table 4. With the exception of Cu, dietary energy and protein levels had no effect on the concentrations of minerals in the yolk or albumen. Cu concentration was significantly higher in the egg yolk of birds fed the low-energy diet (0.95 mg/kg) compared with those fed the higher-energy diets (about 0.66 mg/kg; $P = 0.03$). There was a tendency for higher Cu concentration in eggs from birds fed the 10.5 and 12% protein diets (0.80 – 0.87 mg/kg) compared with birds fed the 13.5% protein diet (0.60 mg/kg; $P = 0.09$). There were no significant differences in mineral concentrations in the albumen of birds fed different energy level diets, and although there were significant differences in the albumen of birds fed different protein diets, these differences were small and showed no consistent pattern (Table 4). Of the eight minerals analysed, P, Mg and Fe concentrations were higher in yolk than in albumen. K, Na, and Mn concentrations were higher in albumen than in yolk, and Ca and Cu concentrations were similar in yolk and albumen (Table 4).

DISCUSSION AND CONCLUSION

The shell of ostrich eggs is thick and makes up about 20% of the mass of the egg. This is proportionately more than for other species of birds (Deeming 1997). Albumen makes up about 56% and yolk 24% of fresh egg mass, slightly higher and lower respectively than the 53.4% and 32.5% given by Sales (1996). Albumen and yolk as a proportion of egg contents

(70% and 30% respectively) are similar to the 66% and 34% previously reported (Deeming 1997).

Neither energy nor protein dietary levels have any significant effect on the physical characteristics of ostrich eggs. This is also true, specifically, for the size and mass of poultry eggs (Morris 1985). Similarly, several other studies have suggested that protein levels have no effect on egg production, egg composition and egg size of broiler breeder hens (Lopez *et al.* 1995, Barreto and Ferreira 1999a). Nager *et al.* (1997) found this also to be true for great tits. Barreto and Ferreira (1999b) found that protein levels have no effect on yolk concentration and Hanczakowski *et al.* (1998) found that different animal and plant proteins have only a minor effect on hen performance and no effect on yolk fatty acid composition of eggs produced by laying hens. These findings are consistent with the results of our study but are contrary to the results of several other studies. The proportion of albumen and albumen protein in eggs of cage-reared Starcross layers increased significantly with an increase in dietary protein levels but was not influenced by changing dietary energy content (Uddin *et al.* 1997). Zebra finches whose diets were supplemented with protein laid larger eggs with a greater proportion of yolk and albumen protein (Williams 1996) and it has been suggested that dietary protein may be a direct as well as an indirect factor influencing the allocation of lipid and protein stores in laying birds (Carey 1996). Egg mass and yolk content of broiler breeders also increased as dietary protein and energy increased (Spratt and Leeson 1987). In contrast, increasing the dietary amino acid and protein resulted in an increase in egg mass but a decrease in albumen quality in laying hens (Hammershøj *et al.* 1998). In cage-reared Starcross layers, egg mass increased, but the proportion of yolk mass decreased linearly as dietary protein and energy levels increased (Uddin *et al.* 1997). However, the different dietary protein and energy levels did not significantly influence eggshell mass, albumen and yolk dry matter, yolk lipid or egg energy content (Uddin *et al.* 1997).

Apart from general composition of eggs, Naber (1979) and Badley (1997) also found that some minerals (Ca and P) and amino acids are influenced only slightly or not at all by nutrition. This is in line with our own findings on yolk from breeders fed different dietary levels of protein. We found, however, that energy levels did have an influence on the proportion of water and ash. We also found that dietary protein did not significantly affect mineral and amino acid composition, whereas different energy levels did appear to have some effect on the amino acid composition of albumen. Lopez (1995) found that, although broiler breeders fed the lowest crude protein retain less nitrogen, the nitrogen deposited in the egg was not affected. While the influence of dietary energy levels on amino acid concentrations is not clear, presumably birds fed low-protein diets meet protein and specific amino acid requirements for egg formation from body stores. This confirms the suggestion that the viability of the egg will be maintained even with low crude protein intake.

Du Preez (1991), Angel (1993), and Sales *et al.* (1996) have reported values of ostrich egg composition but these results are not necessarily comparable to ours because they analysed albumen and yolk together whereas we analysed these components separately. Where comparable data are available, it suggests some variations in the protein composition of the albumen in the case of ratite and poultry eggs. The lipid content of ostrich eggs tends to be lower than that of emu eggs (Angel 1993) and poultry eggs (Angel 1993; Sales *et al.*, 1996). Ostrich eggs have a higher leucine and threonine content than poultry eggs, and the total quantity of essential amino acids determined in ostrich eggs is higher than that of chicken eggs (Sales *et al.* 1996). The concentration of the non-essential amino acid alanine is lower in ostrich eggs than in poultry eggs. Concentrations of Ca, Fe, Mg and Zn are similar to those of poultry eggs, whereas Mn and P are lower (Sales *et al.*, 1996).

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CHAPTER 5

THE EFFECT OF THE NUTRITIONAL REGIME IN THE PREVIOUS BREEDING SEASON ON PRODUCTION OF THE NEXT SEASON

ABSTRACT

In a study on ostrich nutrition that spanned three breeding seasons, I assessed the effect of different dietary energy and protein levels in the previous breeding season on production in the following breeding season. During the first breeding season, groups of breeding ostriches were fed diets with energy levels of 8.5, 9.5 and 10.5 MJ/kg dry mass (DM) metabolisable energy (ME) and protein levels of 13.5, 15 and 16.5%. Amino acid profile was balanced, and was related to the protein content in all cases. In the second breeding season, groups were fed diets with levels of 7.5, 8.5 and 9.5 MJ/kg ME and protein levels of 10.5, 12 and 13.5%. During the third breeding season, all the breeding birds were fed a single diet of 9.5 MJ/kg ME and 12% protein. Different levels of dietary protein in previous years had no effect on egg production, egg mass, fertility, hatchability and initial chick mass in subsequent years of production. Different levels of dietary energy in previous years had no significant effect on the body mass of breeding females, initial egg mass or the percentage of infertile eggs produced over the three seasons, but females fed diets containing only 7.5 MJ/kg ME during the second year produced significantly fewer eggs in the third breeding season, resulting in fewer chicks hatched. We conclude that there are potential carry-over effects of dietary energy levels from one year to the next and that an energy level of less than 8.5 MJ/kg DM in the diet may have a negative effect on egg production in breeding female ostriches.

INTRODUCTION

Although there has been a thriving ostrich industry in South Africa for more than a century, relatively little is known about the specific nutritional needs of ostriches. Studies on the metabolisable energy of specific components of diet formulations and various balanced diets have shown that ostriches have enhanced digestive capacity compared with poultry (Cilliers 1994, Brand *et al.* 2000a). Salih *et al.* (1998) and Brand *et al.* (2000b) have shown that feeding young ostriches low-energy diets has no effect on their growth rate. Little is known, however, about the specific nutritional needs of adult ostriches during the breeding season. Nutrition plays an important role in egg production in female birds and has to meet nutritional requirements for the maintenance of body condition and nutrients for egg production (Carey 1996). This may be especially important in female ostriches on commercial farms, where the repeated removal of eggs for artificial incubation causes these birds to lay several times the normal number of eggs in a breeding season. The ostrich industry is subject to market trends, and in times of economic hardship there is pressure on ostrich farmers to reduce production costs. Because feeding costs represent about 70 - 80% of the total production cost, feed quality, especially as far as energy and protein levels are concerned, is often the first to be compromised. Although breeding ostriches appear to perform equally well on lower and higher energy and protein diets, too low an energy level is a limiting factor in egg production (Chapter 2). The longer-term effects of reduced dietary energy and protein levels are, however, not known. A study over two breeding seasons to assess the effect of different dietary energy and protein levels on production in breeding female ostriches allowed me to assess the effect of the nutritional regimes followed in previous breeding seasons on production in breeding female ostriches in the following year.

MATERIALS AND METHODS

Experimental birds used in the study were African black ostriches from the commercial ostrich breeding flock at the Klein Karoo Agricultural Development Centre near Oudtshoorn, South Africa. Management of the breeding flock was described by Van Schalkwyk *et al.* (1996), and egg collection, subsequent treatment and incubation by Van Schalkwyk *et al.* (1998).

The trial ran over three breeding seasons (1998/1999, 1999/2000 and 2000/2001). For the first and second breeding season ninety pairs of adult breeding ostriches were divided randomly into nine groups of ten pairs/group group during each experimental year. Groups therefore had different breeding pairs during each successive breeding season; for example, birds on the low energy diets during the first year were divided into the three energy groups the second year. The same applied to the medium and high-energy groups. The breeding pairs were kept in separate breeding pens throughout the whole of the breeding season. During the first breeding season, groups were fed diets with energy levels of 8.5, 9.5 and 10.5 MJ/kg dry mass (DM) metabolisable energy (ME) and protein levels of 13.5, 15 and 16.5%. Corresponding lysine levels were 0.65, 0.75 and 0.85%. In the second breeding season, groups were fed diets with levels of 7.5, 8.5 and 9.5 MJ/kg ME and protein levels of 10.5, 12 and 13.5%. Corresponding lysine levels were 0.49, 0.59 and 0.69%. All other amino acids were balanced according to requirements. Diets fed are described in detail in Chapter 2. In the third breeding season, all the breeders were fed the same diet, which contained 9.5 MJ/kg ME and 12% protein with a lysine level of 0.59. Diet formulation was based on values presented in the Elsenburg Ostrich Feed Databases (Brand 2000). The feed was milled to pass a 3-mm sieve and pelleted. Each bird was given a ration of 2.5 kg DM/day throughout the breeding season (June – January). Body mass of the female ostriches was determined at the beginning and end of the breeding season. Egg production, egg mass and fate of eggs set in the incubator were recorded throughout each breeding season. Data were analysed according to 3 energy x 3 protein factorial design, in which the energy and protein levels of the previous year featured as the main factors (Statgraphics, 1991).

RESULTS

No significant interactions between energy and protein levels were observed. The main effects of the different energy and protein levels in the diet are consequently presented separately.

Energy levels

Mean body mass of females at the start of the first breeding season averaged between 115 and 120 kg and did not differ significantly ($P > 0.40$; Table 1). Females on all diets lost on average between 16.7 and 18.3 kg over the course of the breeding season, but their body mass did not differ significantly at the end of the season ($P > 0.20$; Table 1). There was an increase in the mass of birds in all groups during the rest period. At the beginning of the second breeding season the mass of female ostriches ranged between 112 and 117 kg ($P > 0.50$). Mass of birds at the end of the season had increased or remained the same but did not differ significantly at the end of the season. During the third breeding season, all birds were fed the same diet (9.5 MJ/kg) and gained between 0.10 and 9.5 kg over the course of the breeding season. Their mass did not differ significantly at the end of the season ($P > 0.50$; Table 1).

Table 1. The effect of dietary energy levels received in the previous year on production of female ostriches during the successive year. (Mean ± SE)

Production Parameters	PRODUCTION IN THE FIRST SUCCESSIVE YEAR Energy level (MJ/kg) fed the previous year			Significance Level (P)	PRODUCTION IN THE SECOND SUCCESSIVE YEAR Energy level (MJ/kg) fed the previous year			Significance Level (P)
	8.5	**9.5**	**10.5**		**7.5**	**8.5**	**9.5**	
Number of animals, n	20	18	23		20	21	20	
Starting mass, kg	114.6 ± 3.2	119.9 ± 3.4	119.8 ± 3.0	0.420	111.9 ± 3.0	117.2 ± 4.3	115.3 ± 3.1	0.557
End mass, kg	96.3 ± 3.3	102.0 ± 3.5	103.1 ± 3.1	0.288	120.0 ± 4.6	117.3 ± 6.3	124.8 ± 4.6	0.594
Production								
Egg production, n	47.4 ± 5.3	46.0 ± 5.6	40.8 ± 5.0	0.632	28.7 ± 4.5^{a}	51.3 ± 6.3^{b}	40.6 ± 4.6^{ab}	0.016
Live chicks hatched, n	27.7 ± 4.4	25.4 ± 4.6	23.1 ± 4.1	0.753	14.2 ± 3.7^{a}	30.8 ± 5.1^{b}	23.2 ± 3.7^{ab}	0.033
Live chicks hatched, %	57.3 ± 5.5	48.8 ± 5.8	56.7 ± 5.2	0.503	40.8 ± 6.6	58.8 ± 9.0	50.7 ± 6.5	0.253
Hatchling mass, g	876.1 ± 18.8	855.6 ± 20.6	862.9 ± 17.0	0.752	874.6 ± 10.4^{a}	842.8 ± 11.0^{b}	876.8 ± 10.6^{a}	0.059
Egg mass								
Initial mass, g	1452.0 ± 23.8	1448.4 ± 25.8	1435.1 ± 22.3	0.861	1438.6 ± 28.8	1418.4 ± 31.1	1391.6 ± 24.2	0.455

^{a,b} Denote significant ($P \leq 0.05$) difference in rows.

Table 2. The effect of dietary protein levels received in the previous year on production of female ostriches during the successive year. (Mean ± SE)

Production Parameters	PRODUCTION IN THE FIRST SUCCESSIVE YEAR Protein (%) fed the previous year			Significance Level (P)	PRODUCTION IN THE SECOND SUCCESSIVE YEAR Protein (%) fed the previous year			Significance Level (P)
	13.5	**15.0**	**16.5**		**10.5**	**12.0**	**13.5**	
Number of animals, n	24	13	24		23	17	21	
Starting mass, kg	121.0 ± 3.2	115.9 ± 3.1	117.6 ± 3.3	0.522	113.7 ± 3.2	115.9 ± 3.9	114.8 ± 3.4	0.910
End mass, kg	105.7 ± 3.3	97.2 ± 3.2	98.6 ± 3.4	0.157	123.3 ± 4.7	114.6 ± 5.7	124.3 ± 5.1	0.393
Production								
Egg production, n	38.5 ± 5.3	42.7 ± 5.2	53.0 ± 5.4	0.156	41.1 ± 4.6	43.3 ± 5.8	36.2 ± 5.1	0.621
Live chicks hatched, n	21.7 ± 4.4	26.7 ± 4.3	28.1 ± 4.5	0.575	24.8 ± 3.9	19.5 ± 4.7	24.0 ± 4.1	0.661
Live chicks hatched, %	48.8 ± 5.5	60.6 ± 5.4	53.5 ± 5.6	0.309	55.8 ± 6.8	37.6 ± 8.2	57.0 ± 7.2	0.154
Hatchling mass, g	865.8 ± 20.3	845.5 ± 17.6	883.4 ± 18.5	0.334	878.0 ± 9.2	864.9 ± 10.4	851.3 ± 12.1	0.225
Egg mass								
Initial mass, g	1452.6 ± 24.6	1418.7 ± 23.1	1464.3 ± 24.2	0.372	1451.7 ± 23.9	1381.2 ± 29.5	1415.6 ± 30.6	0.187

^{a,b} Denote significant ($P \leq 0.05$) difference in rows.

Egg production in the first season following the year in which birds were subjected to different nutritional regimes ranged from 40 to 47 eggs/female and did not differ significantly for the various groups ($P > 0.15$; Table 1). Similarly, the proportion of chicks hatched and hatchling mass did not differ significantly for birds fed different energy level diets the previous year (Table 1). During the second breeding season, after different feeding regimes had been followed, egg production ranged between 29 and 51 eggs/female. Females fed the 7.5 MJ/kg ME diet the previous year lay significantly fewer eggs ($P < 0.02$; Table 1) than the breeders fed the 8.5 MJ/kg ME diet the previous year, but did not differ from those fed the 9.5 MJ/kg diet the previous year. The number of chicks hatched from females fed the 7.5 MJ/kg ME diet (14.2) was also significantly lower than the 30 chicks hatched from birds fed the 8.5 MJ/kg ME diet the previous season ($P < 0.025$), although difference in hatching weight only approached significance ($P = 0.059$). Lower energy level fed in a previous year seems to have no negative effect on the percentage of chicks hatched or chick hatch weight. No significant different occurred in the initial egg weight between the different treatments.

Protein levels

The mean mass at the start and end of the first breeding season did not differ significantly between groups assigned to different dietary protein levels ($P > 0.10$) fed the previous year. Again, all birds gained mass during the rest period. During the second breeding season no significant differences in mass were evident at the start ($P > 0.90$). The females on the 12% protein diet lost 1.3kg by the end of the season, whereas those on the 10.5 and 13.5% protein diets gained between 9.2 and 9.6 kg. The mean mass of the groups did not differ significantly ($P > 0.39$; Table 2). No significant difference was found between the various treatments during the first breeding season. No significant difference was evident in the percentage of chicks hatched from eggs produced by birds fed different levels of dietary protein ($P > 0.5$) or the hatchling mass. During the second breeding season the egg production was between 36.2 and 43.3 eggs/female, but no significant difference was found between groups fed the different diets in the previous season ($P > 0.62$) nor was there a significant difference in egg mass, proportion of chicks hatched or hatchling mass.

DISCUSSION AND CONCLUSIONS

Provision of adequate and appropriate nutrition is especially important for females to maintain their egg production from season to season. There are apparently no reports onsuch carry-over effects in other species of birds. Such effects may, however, not always be evident with domestic poultry owing to the fact that the length of their production cycle does not compare with that of ostriches. Although neither energy nor protein had a carry-over effect on the mass of breeding ostrich females, an energy levels of 7.5 MJ/kg fed in the previous breeding season seemed to reduce egg production in the successive season. Although low dietary energy levels in the previous season had no effect on the hatchling mass, the proportion of chicks hatched from these birds was also lower. It may be concluded from this study that, although birds may be able to recover their body mass fully after a period of being fed very low quality diets, a diet of less than 8.5 MJ/kg DM may reduce production of female ostriches in the successive year.

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CHAPTER 6

CONCLUSION

CONCLUSION

The study was conducted to determine the effect of different dietary energy and protein levels on the production of breeding ostriches. This included body condition of the breeding birds, egg production of females, fertility of males, egg composition and the effect of nutrition of the previous season on the subsequent year's production. The objective was to maintain high egg production, with good egg quality, high fertility, high hatchability, and high chick survival without over- or under-feeding the birds. The findings of the trials are reported in detail in the individual chapters and therefore only general conclusions will be summarized here.

Egg production in birds is costly in terms of energy and nutrients. The required energy and nutrients for egg formation may be derived from daily food intake or from stored reserves. Daily food intake is probably a more important source of nutrients for birds that lay many eggs. This applies particularly to commercial species like poultry and ostriches where the principal objective is to maximize egg or chick production. Provision of adequate and appropriate nutrition is therefore especially important in such species. If energy (or nutrients) are limiting, birds can compensate by reducing egg size, reducing the number of eggs laid, or by increasing the laying interval and spreading the cost of egg formation over a longer period. In ostriches, egg production was not affected in birds fed diets containing between 8.5 and 10.5 MJ/kg ME, but birds fed on diets with only 7.5 MJ/kg ME laid significantly fewer eggs at a laying interval almost twice that of birds fed higher energy diets, which resulted in fewer chicks hatched. Furthermore, female ostriches fed on diets with a low energy content (7.5 and 8.5 MJ/kg ME) generally lost body mass and weighed significantly less by the end of the season than birds fed diets with higher energy levels. They also showed decreases in thoracic and abdominal girth, suggesting a general loss of body condition and nutritional stress. In contrast, different levels of dietary protein between 10.5 and 16.5% had little effect on egg production, laying interval, egg mass, or hatchability and, although birds fed different levels of dietary protein lost mass and body condition, mass and body measurements did not differ significantly at the end of the breeding season. These results indicate that in ostriches, energy rather than protein is potentially the main constraint on egg production.

Chick weight, growth rate and mortality were used as indicators to measure offspring performance. In ostriches, different levels of dietary energy and protein had no significant effects on the mean mass of eggs laid, the mean mass of hatchlings, or their survival to one-month-old.

Energy appears to be the main constraint to egg production in breeding ostriches. Birds fed low energy diets laid fewer eggs at longer intervals compared to birds fed higher energy diets and lost more body condition over the course of the breeding season. Birds fed on diets containing 9.5 and 10.5 MJ/kg ME generally put on mass or lost less. In contrast, different levels of dietary protein showed no significant effects between experimental groups. It may be concluded from this study that a diet containing at least 8.5 MJ ME / kg DM and 10.5% protein are sufficient for female breeding ostriches. Future studies are necessary to find the minimal protein requirement for ostrich breeders. In our study, the female birds regain their original live masses within four months during the resting period, but body measurements suggest they may not have fully recovered body reserves.

Male ostriches fed on high-energy diets (9.5 and 10.5 MJ/kg ME) generally gained weight over the course of the breeding season. Their thoracic girth, abdominal girth and tail circumference also increased over the breeding season which, combined with the increase in body mass, suggests that they were overfed and laid down fat deposits. Birds fed on a diet containing 8.5 MJ/kg ME either gained little weight or maintained weight and showed slight decreases in thoracic and abdominal girth and tail circumference. In contrast birds fed on a low energy diet containing only 7.5 MJ/kg ME lost a substantial amount of weight and showed substantial decreases in thoracic and abdominal girth and tail circumference. Taken in conjunction with the large loss of body weight, this suggests that these birds lost condition during the breeding season. Since most other domestic animal species are managed to lose weight during their breeding seasons, it would seen like the dietary energy levels of 7.5 or 8.5 MJ/kg are the most desirable for breeding male ostriches.

Birds on all protein levels similarly gained weight during the first breeding season and although a slight weight decrease occurred during the second season, it seem that protein levels between 10.5% and 16.5% did not effect the mass or other measurements differently. In this study, there was no significant difference in the fertility of eggs between birds fed the different protein levels. It may be concluded from this study that a dietary energy level of 7.5 MJ ME / kg DM and a protein level of 10.5% in diets of breeding male ostriches are sufficient if mass gain is the main criteria for adjusting rations. The practical implications of this are, however, probably difficult to implement under present commercial farming practices where males and females birds are maintained together in camps, which makes dietary segregation impractical.

The shell of ostrich eggs is thick and made up about 20% of the mass of the egg. This is proportionately more than other species of birds (Deeming, 1997). Albumen comprised about

56% and yolk 24% of fresh egg mass, slightly higher and lower, respectively than the 53.4% and 32.5% given by Sales (1996). Albumen and yolk as a proportion of egg contents (70 and 30%, respectively) are similar to the 66% and 34% previously reported (Deeming 1997). Neither dietary energy nor protein levels had any significant effect on the physical characteristics of ostrich eggs, specifically the size and weight of eggs. Similarly, several other studies have suggested that protein had no effect on egg production egg composition and egg size of broiler breeder hens (Lopez *et al.* 1995, Barreto and Ferreira 1999). I found, however, that energy levels did have an influence on the total percentage yolk, and proportions of water and ash. I also found that dietary protein did not significantly affect mineral and amino acid composition whereas different energy levels did appear to have some effect on the amino acid composition in albumen. Lopez (1995) found in a study that, although broiler breeders fed the lowest crude protein retain less nitrogen, the nitrogen deposited in the egg was not affected. While the influence of dietary energy levels on amino acid concentrations is not clear, presumably birds fed on low protein diets meet protein requirements and specific amino acid needs of the eggs from body stores. This reaffirms the concept that the viability of the egg will apparently be maintained even at low dietary crude protein intake. In real terms, feeding of diets with different energy and protein levels to laying female ostriches appeared to have little affect on egg composition and chick production.

Provision of adequate and appropriate nutrition is especially important for females to maintain their egg production from season to season. There are apparently no reports on such carry-over effects in other species of birds. Such effects may, however, not always be evident with domestic poultry because the length of their production cycle does not compare to that of ostriches. Although neither energy nor protein had a carry-over effect on the mass of breeding ostrich females, energy levels of 7.5 MJ/kg fed in the previous breeding season seems to reduce egg production in the successive season. Although low dietary energy levels in the previous season had no effect on the hatchling mass, the proportion of chicks hatched by these birds was also lower. It may be concluded from this study that although birds may fully recover their body weight after a period fed very low quality diets, a diet less than 8.5 MJ/kg DM may reduce production of female ostriches in the successive year.

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