The effect of dietary energy and protein levels on body condition and production of breeding male ostriches

Z. Brand[1,2#], T.S. Brand[3] and C.R. Brown[4*]
[1]Little Karoo Agricultural Development Centre, P.O. Box 351, Oudtshoorn 6620, South Africa
[2]Klein Karoo Co-operative, P.O. Box 241, Oudtshoorn 6620, South Africa
[3]Elsenburg, Agricultural Research Centre, Private Bag X1, Elsenburg 7607, South Africa
[4]Department of Zoology and Entomology, Rhodes University, Grahamstown 6139, South Africa

Abstract

In a study over two breeding seasons we assessed the effect of different energy and protein levels in the diet of male ostriches on their body weight, body condition and the fertility of the eggs produced by their females. During the first season, the birds were fed diets with energy levels of 8.5, 9.5 or 10.5 MJ metabolisable energy (ME)/kg dry matter (DM) and 13.5, 15.0 or 16.5% protein. Corresponding lysine concentrations were 6.5, 7.5 and 8.5 g/kg. In the second breeding season the groups were fed diets with energy levels of 7.5, 8.5 and 9.5 MJ ME/kg and protein levels of 10.5, 12.0 and 13.5%. Corresponding lysine concentrations were 4.9, 5.9 and 6.9 g/kg. During the first breeding season the weight of all birds increased, but the weight of those fed the 8.5 MJ ME/kg DM diet was significantly lower at the end of the season than that of birds fed diets containing 9.5 and 10.5 MJ ME/kg DM. During the second season the trend in the case of the 8.5 and 9.5 MJ ME/kg diets was the same as in the previous season, but a significant decrease in weight occurred in birds fed the 7.5 MJ ME/kg DM diet. A general loss in body condition occurred at all energy levels. In contrast, protein level 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. We concluded from this study that levels of 8.5 MJ ME/kg DM and 10.5% protein in the diet of breeding male ostriches are sufficient if maintenance in weight is the main criteria for formulating rations.

Keywords: Ostriches, breeders, nutrition, protein levels, amino acid levels, energy levels
[#] Corresponding author. E-mail: zanellb@wcape.agric.za
* Present address: Hartpury College, Hartpury, Gloucestershire, GL19 3BE, England

Introduction

Successful intensive commercial farming of ostriches (*Struthio camelus domesticus*) requires an adequate knowledge of the nutritional needs of the birds and of the components used in formulating diets. 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 used widely, but 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 on metabolisable energy (ME) levels in balanced diets have indicated that ostriches have a more effective digestive capacity to utilise high fibrous diets than other poultry species (Cilliers, 1994; Brand *et al*., 2000). Studies by Salih *et al*. (1998) and Brand *et al.* (2000), for example, indicated that low-energy diets had no adverse effect on the growth rate of young ostriches. Consequently, lower energy diets can be fed to growing/finishing ostriches up to slaughter age with no adverse effects on production, but with obvious financial implications. Furthermore, the hindguts of ostriches are adapted for hemicellulose and cellulose fermentation. Volatile fatty acids produced in the hindgut comprise between 12% and 76% of the daily ME intake of growing ostriches (Swart, 1988). High levels of dietary protein also appear to be unnecessary for ostriches. The growth rate and food consumption of growing ostriches (60 – 110 kg) fed a 14.0% protein diet were better than those of birds fed diets containing higher levels of protein (Swart & Kemm, 1985).

Lack of knowledge on the specific nutritional needs of breeding ostriches has possibly been a major contributing factor in their historically poor breeding performance. The use of energy values derived from poultry nutrition in ostrich breeder diets has led to obesity in breeding ostriches (Cilliers & Angel, 1999), which could affect breeding performance (Angel, 1993). Overfeeding of breeding birds has been implicated as a factor in the high proportion of infertile eggs produced. Hatchability also decreases in eggs laid by obese broiler breeders (Robinson & Wilson, 1996). In other species such as horses, cattle and pigs, fertility and conception rates decrease and birth rates drop in obese animals, and in both poultry and mammals this effect is more severe at high environmental temperatures. Breeding ostriches from the Little Karoo 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 a much lower incidence of only 11.5% infertile eggs (Smith *et al.*, 1995). The males and females in a paddock were fed the same diet, which was rich in calcium required by laying females, but low in zinc, which is essential for male sperm production. Consequently, male birds tended to consume excessive amounts of food, which could have resulted in obese males with a poor sperm quality. Bramwell *et al.* (1996) observed a significant negative effect of increased dietary energy intake on sperm concentration and total live sperm per ml of ejaculate in male broiler breeders. Soley & Groenewald. (1999) confirmed that obesity in male ostriches could lead to decreased fertility. It has been shown that the nutrient requirements of male and female chickens differ (NRC, 1994), and it can be assumed that there will also be differences in requirements between adult male and female ostriches. Robinson & Wilson (1996) found that the benefits of controlling body weight in male broiler breeders early in the breeding season are evident at the end of the breeding period. Separate-sex feeding has been initiated in the management of broiler breeder flocks and was associated with an increase of about 5% in overall hatchability of eggs (Whitehead, 1989). This increase was brought about by an increase in the fertility of eggs, since the hatchability of fertile eggs was unaffected. Studies of growing birds suggest that there is a potential for ostriches to be fed diets relatively high in fibre, with low energy and protein levels, without compromising production.

In this study we assessed the effect of the level of energy and protein in the diet of breeding males on their body weight and body condition as well as on the fertility of the eggs produced by their females. This information would be particularly valuable to commercial ostrich enterprises because the protein, energy and fibre levels of formulated diets impact heavily on the cost of purchased feeds and consequently on production cost.

Materials and Methods

The 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. The management of the breeding flock has been described previously by Van Schalkwyk *et al.* (1996). The trial ran over two breeding seasons (1998/9 and 1999/2000). Ninety pairs of adult breeding ostriches were divided randomly into nine groups of 10 pairs/group during each experimental year. Therefore, groups had different breeding pairs during each successive breeding season. The breeding pairs were kept in separate breeding pens throughout the breeding season. During the first season birds were fed diets with energy levels of 8.5, 9.5 or 10.5 MJ ME/kg dry matter (DM) and protein levels of 13.5, 15.0 or 16.5%. Corresponding lysine concentrations were 6.5, 7.5 and 8.5 g/kg. The 90 pairs of breeders were again divided randomly for the second season and the groups were fed diets with energy levels of 7.5, 8.5 and 9.5 MJ ME/kg and protein levels of 10.5, 12.0 and 13.5%. Corresponding lysine concentrations were 4.9, 5.9 and 6.9 g/kg. Diet formulation (Tables 1 and 2) was done according to requirement and raw material composition values recommended in the Elsenburg Ostrich Feed Databases (Brand, 2000). For both the first and the second season the diets were analysed according to the AOAC methods (AOAC, 1984) to determine the crude protein and lysine concentrations. The diets of the second season were analysed further to determine the threonine, fat, calcium and phosphorus concentrations. The feeds were milled to pass through a 3.0 mm sieve and then pelleted. 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 weight provided a measurement of body condition. The birds were 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 containing 8.5 MJ ME/kg DM and 9.1% protein (Table 3) to avoid weight gain and excessive weight at the beginning of the following breeding season. The weight of the males was recorded at the end of the rest period to ensure that no substantial increase in weight occurred during this period. Data were analysed according to a 3 energy x 3 protein factorial design, with protein and energy levels featuring as main factors (Statgraphics, 1991).

Table 1 Composition of the nine experimental diets fed to breeding birds during the first breeding season

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8	Diet 9
Ingredients (g/kg)									
Lucerne	605.5	605.5	605.5	605.5	605.6	605.5	605.5	605.5	605.5
Oat bran	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 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	8.5	8.5	8.5	9.5	9.5	9.5	10.5	10.5	10.5
Protein, %*	13.5	15.0	16.5	13.5	15.0	16.5	13.5	15.0	16.5
Lysine, g/kg*	6.5	7.5	8.5	6.5	7.5	8.5	6.5	7.5	8.5
Met-cys**, g/kg	4.5	5.3	6.1	4.5	5.3	6.1	4.5	5.3	6.1
Tryptophan, g/kg	2.5	2.9	3.2	2.6	2.9	3.3	2.6	3.0	3.3
Threonine, g/kg	4.8	5.7	6.5	5.1	5.9	6.7	5.3	6.1	6.8
Crude fibre, g/kg	256.0	250.7	245.3	225.5	223.3	221.2	195.0	196.0	197.0
Fat, g/kg	14.0	13.5	13.0	17.1	16.5	15.9	20.2	19.5	18.7
Calcium, g/kg	20	20	20	20	20	20	20	20	20
Phosphorus, g/kg	8.0	8.8	9.6	8.0	8.4	8.8	8.0	8.0	8.0

*Analysed, **Methionine + cystine

Table 2 Composition of the nine experimental diets fed to breeding birds during the second breeding season

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8	Diet 9
Ingredients (g/kg)									
Lucerne meal	138.6	69.3	0.0	280.5	216.7	152.9	422.3	364.0	305.7
Oat bran	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	7.5	7.5	7.5	8.5	8.5	8.5	9.5	9.5	9.5
Protein, %*	10.5	12.0	13.5	10.5	12.0	13.5	10.5	12.0	13.5
Lysine, g/kg*	5.4	5.7	6.1	5.4	5.4	6.1	5.4	5.7	6.1
Met-cys**, g/kg	3.7	4.6	5.4	3.7	4.5	5.4	3.7	4.5	5.4
Tryptophan, g/kg	1.2	1.3	1.4	1.6	01.7	1.9	1.9	2.1	2.3
Threonine, g/kg*	3.3	3.5	3.8	3.3	3.5	4.8	3.3	3.5	3.8
Crude fibre, g/kg	235.5	222.6	209.6	220.4	211.0	201.7	205.3	199.5	193.7
Fat, g/kg*	16.6	19.2	18.4	16.6	17.3	18.4	21.4	21.2	18.4
Calcium, g/kg*	15.5	15.1	19.5	18.6	18.3	19.9	17.9	18.8	17.2
Phosphorus, g/kg*	9.3	8.7	11.3	9.8	10.4	10.6	10.3	10.5	10.2

*Analysed, **Methionine + cystine

Table 3 Composition of the diet fed to the males during the rest period

	Diet
Ingredients (kg/ton)	
Lucerne	112.8
Oat bran	567.2
Barley	287.6
Limestone	25.0
Salt	5.0
Mineral & vitamin premix	2.0
Synthetic methionine	0.4
Total	1000.0
Composition: (calculated)	
ME, MJ/kg	8.5
Protein, %	9.1
Lysine, g/kg	2.7
Met-cys, g/kg	2.1
Methionine, g/kg	1.3
Threonine, g/kg	2.2
Tryptophan, g/kg	1.4

Results

There were no interactions between the effects of dietary 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 weight of birds was between 117 and 123 kg and did not differ ($P > 0.05$) between the various groups. During the first breeding season (1998/9) the birds gained between 4 and 15 kg in body weight over the course of the breeding season, with those birds fed the lowest energy diets experiencing the lowest increase in weight and those fed the highest energy diet the most. At the end of the season, the body weight of those birds fed the 8.5 MJ ME/kg diet was less ($P \leq 0.001$) than that of the birds fed diets containing 9.5 and 10.5 MJ ME/kg. At the beginning of the breeding season there were no differences ($P > 0.05$) 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 ME/kg increased over the breeding season. In contrast, measurements of those birds fed the diet containing 8.5 MJ ME/kg decreased and were less ($P \leq 0.001$) than those of birds fed the higher-energy diets. Taken in conjunction with the relatively small increase in body weight, this suggests that these birds did not accumulate fat during the breeding season. The weight of all birds decreased during the four-month rest period, and at the end of that period their body weight was back to pre-breeding season levels, with no differences ($P > 0.25$) between groups (Table 4).

The mean weight of the birds at the start of the second breeding season trial (1999/2000) was similar to that in the first season (between 117 and 123 kg) and again, there were no differences ($P > 0.20$) between groups (Table 4). During the second breeding season, the body weight of birds fed the 8.5 and 9.5 MJ ME/kg diets increased on average by 0.6 and 6.4 kg, respectively, although the mean weight of both groups at the end of the season did not differ significantly. In contrast, the body weight of birds fed the diet containing 7.5 MJ ME/kg decreased by 12.5 kg and was less ($P \leq 0.001$) 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 difference ($P > 0.2$) 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 weight of birds fed the 7.5 MJ ME/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 weight at the start of the breeding season.

Table 4 The effect of different dietary energy levels on body weight, body measurements and production of breeding male ostriches over two breeding seasons (mean ± s.e.)

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 weight, 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 weight, 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
Weight 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 weight, 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 within rows

Table 5 The effect of different dietary protein levels on live body weight, body measurements and production of breeding male ostriches over two breeding seasons (mean ± s.e.)

Production parameters	Protein (%) first season (1998/9)			Significance level (P)	Protein (%) second season (1999/2000)			Significance level (P)
	13.5	15.0	16.5		10.5	12.0	13.5	
Number of animals, n	30	30	30		30	30	30	
Starting weight, 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 weight, 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
Weight weight, 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 weight, 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 within rows

The proportion of infertile eggs over the two seasons ranged between 8 to 27%. There were no trends evident in the proportion of fertile eggs in relation to dietary energy levels, and mean values did not differ (P > 0.05) for the various treatment groups in any one season (Table 4).

The effects of different protein levels on body weight and body measurements over the two breeding seasons are presented in Table 5. Again, the weight of birds assigned to different diets did not differ (P > 0.05) 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 weights at the end of the season did not differ significantly (P > 0.25). Thoracic and abdominal girth and tail circumference generally increased slightly (Table 5), but did not differ significantly between birds fed different diets. During the second breeding season, all birds experienced a decrease in weight. The decrease in weight ranged between 0.3 and 2.6 kg, but final body weight in the various groups did not differ significantly (Table 5). Thoracic and abdominal girth and tail circumference decreased, but again, at the end of the season, did not differ (P > 0.05) between birds fed different diets. Males generally experienced a decrease in weight during the first rest period. At the end of the rest period their body weight corresponded closely with their weight 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, the birds gained between 4 and 9 kg. The increase in weight corresponded with the proportion of protein in the diet, but mean weights at the end did not differ significantly (P > 0.05).

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

Discussion and Conclusion

Male ostriches fed high-energy diets (9.5 and 10.5 MJ ME/kg DM) generally experienced an increase in weight 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 weight, suggests that they were overfed and deposited fat. The body weight of birds fed a diet containing 8.5 MJ ME/kg DM was either slightly more or remained the same, and there was a slight decrease in thoracic and abdominal girth and tail circumference in these birds. In contrast, birds fed a low-energy diet containing only 7.5 MJ ME/kg experienced a substantial decrease in weight 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 weight, suggests that these birds lost condition during the breeding season. Since most other domestic animal species are managed to bring about a decrease in weight during the breeding season, the dietary energy levels of 7.5 or 8.5 MJ ME/kg would seem to be the most desirable for breeding male ostriches. Birds on all protein levels similarly experienced an increase in weight during the first breeding season, and although a slight decrease in weight occurred during the second season, it seems as if protein levels ranging between 10.5% and 16.5% did not affect body weight or body measurements. In a trial with male turkeys, Cecil (1982) found that the concentration of semen collected from males on different protein diets (8, 11, 13 and 17%) was similar and fertility and hatchability of eggs did not differ between the various treatments. Dobrescru (1986) and Sexton (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.

Despite losing body weight and condition on a low energy-low protein diet, there was no evidence that fertility was affected. Similarly, despite substantial weight gains and apparent deposition of fat (as indicated by increased body measurements) of some groups, there were no significant differences or consistent trends in the proportion of infertile eggs produced. This is in contrast to previous assertions with regard to obesity and fertility in male ostriches (Angel, 1993; Smith *et al.*, 1995; Soley *et al.*, 1999). From our results, it may be concluded that levels of 8.5 MJ ME/kg DM and 10.5% protein in the diet of breeding male ostriches are sufficient if an increase in body weight during the breeding season is the main criterion for formulating rations.

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References

Angel, R., 1993. Obesity and reproduction. The Ostrich Discussion Group News, April 1993.

AOAC, 1984. Official Methods of Analysis, (13th ed.). Association of Official Analytical Chemists, Washington DC.

Bramwell, R.K., McDaniel, C.D., Burke, W.K., Wilson, J.L. & Howarth, B., 1996. Influence of male broiler breeder dietary energy intake on reproduction and progeny growth. Poult. Sci. 75, 767-775.

Brand, T.S., 2000. Elsenburg Ostrich Feed Databases. Elsenburg Agricultural Research Centre, Private Bag X1, Elsenburg 7607, South Africa.

Brand, T.S., Nel, C.J. & Van Schalkwyk, S.J., 2000. The effect of dietary energy and protein level on the production of growing ostriches. Proc. 38th Congr. S. Afr. Soc. Anim. Sci., June 2000.

Cecil, H.C., 1982. Effect of frequency of semen collection on reproductive performance of male turkeys fed low protein diets during the breeder period. Poult. Sci. 61, 1866-1872.

Cilliers, S.C., 1994. Evaluation of feedstuffs and the metabolisable energy and amino acid requirements for maintenance and growth in ostriches (*Struthio camelus)*. PhD (Agric) thesis, University of Stellenbosch, South Africa.

Cilliers, S.C. & Angel, C.R., 1999. Basic concepts and recent advances in digestion and nutrition. In: The ostrich: biology, production and health. Ed. Deeming, D.C., CAB Publishers, Wallingford. pp. 105-128.

Deeming, D.C., Sibly, R.M. & Magole, I.L., 1996. Estimation of weight and body condition of ostriches *(Struthio camelus)* from body measurements. Vet. Rec. 139, 210-213.

Dobrescu, O., 1986. Photoperiod, diet and method of feeding in reproduction. Poult. Sci. 65, 559-564.

NRC, 1994. Nutrient requirement of poultry (9th ed.). National Academy Press. Washington, D.C., USA.

Robinson, F.E. & Wilson, J.L., 1996. Reproductive failure in overweight male and female broiler breeders. Anim. Fd. Sci. Technol. 58, 143-150.

Salih, M.E., Brand, T.S., Van Schalkwyk, S.J., Blood, J.R., Pfister, A.P., Brand, Z. & Akbay, R., 1998. The effect of dietary fibre level on the production of growing ostriches. Proc. 2nd Int. Ratite Conf., September 1998, Oudtshoorn, South Africa. pp. 31-37.

Sexton, T.J., 1986. Effect of dietary protein and season on fertility of turkey semen stored 18 hours at 5°C. Poult. Sci. 65, 604-606.

Smith, W.A., Cilliers, S.C., Mellett, F.D. & Van Schalkwyk, S.J., 1995. Ostrich production – A South African perspective. In: Biotechnology in the Feed Industry. Proc. Alltech's 11th Ann. Symp. Eds. Lyons, T.P. & Jacques, K.A., Nottingham University Press, Nottingham, United Kingdom. pp.175-197.

Soley, J. T. & Groenewald, H. B., 1999. Reproduction. In: The ostrich: biology, production and health. Ed. Deeming, D.C., CAB International, Wallingford. pp. 129-158.

Statgraphics 5.0, 1991. Statistical Graphic System. Statistical Graphics Corporation Inc., 2115 East Jefferson Street, Rockville, MD 20852, pp. 015-033.

Swart, D. & Kemm, E.H., 1985. The effect of protein and energy levels on the growth performance and feather production of slaughter ostriches under feedlot conditions. S. Afr. J. Anim. Sci. 15, 146-150.

Swart, D., 1988. Studies on the hatching, growth and energy metabolism of ostrich chicks (*Strutio camelus* var *domesticus*). PhD (Agric) thesis, University of Stellenbosch, South Africa.

Van Schalkwyk, S.J., Cloete, S.W.P. & De Kock, J.A., 1996. Repeatability and phenotypic correlation for bodyweight and reproduction in commercial ostrich breeding pairs. Br. Poult. Sci. 37, 953-962.

Whitehead, C.C., 1989. Nutrition of the breeding bird and developing embryo. In: Avian incubation. Ed. Tullett, S.G., Butterworth – Heinemann, London. pp. 227-238.