The Nutrition Requirements and Foraging Behaviour of Ostriches

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ABSTRACT : Ostrich farming is a developing industry in most countries in the world, with farm profitability being largely dependent on the quality of the products, especially skins and meat. To produce quality products, it is essential to ensure that nutrient supply matches the nutrient requirements of ostriches during their growth. To achieve this, information on feed utilisation efficiency and nutrient requirements of ostriches at different maturity stages is required. In South Africa, a number of experiments were carried out to assess the nutritive value of feed and to define the nutrient requirement of ostriches. These data were derived from limited number of birds and the direct application of the results to ostrich farming in Australia and other countries is questionable due to the difference in environment and feed resources. Initially ostrich farmers used data from poultry as a guideline for feed formulation, but in recent years more data has become available for ostriches. Ostriches have a better feed utilisation efficiency and a larger capacity of using high fibre feeds such as pastures than poultry. This review revealed that there are a number of areas there further nutritional research and development is required to ensure the ostriches are provided suitable diets to maximise farm profitability. These include the assessment of the nutritive value of feed ingredients for ostrich chicks and adult birds, the determination of nutrient requirements of ostriches under different farming systems, the development of ostrich diet for producing specific product, and grazing management strategies of ostriches in a crop-pasture rotation system. *(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 5 : 773-788)*

Key Words : Fibrous Feeds, Nutrient Requirement, Feed Digestibility, Digestive System, Ostrich Farming, Grazing

INTRODUCTION

Ostrich farming commenced in South Africa in 1863. In ancient times. feathers were used to decorate the headdresses of Egyptian queens as well as Greek and Roman generals. The eggs were used as water-containers by bushmen and to decorate the crosses of Coptic churches in Ethiopia (Earle. 1994).

Two different methods are used in the literature to classify the ostrich species. Smit (1963) recognised four species of ostrich: 1) the North African *(Struthio camelus* Linnaeus). 2) East African *(Struthio massaicus* Neumann), 3) Somali *(Struthio molybdophanes* Reichenow). and 4) South African *(Struthio australis* Gurney). Other researchers. however, classified all African ostriches as one species. the *Struthio camelus* with four varieties (Goodman et al., 1983: Swart. 1988; Stewart. 1989a). Together with the above four varieties a cross between South African and North African ostriches. *Struthio camelus domesticus.* is recognised as a fifth variety. and is farmed extensively in South Africa (Smit. 1963: Brown et al.. 1982: Swart. 1988).

In the wild. ostriches forage on patches of green vegetation in arid environments (Williams et al., 1993) and feed on a wide range of plant. fruit and vegetable species (Smit. 1963: Robinson and Seely. 1975: Kok. 1980: Keffen. 1984: Williams et al., 1993: Earle, 1994). Ostriches are able to survive in areas with high temperatures and poor vegetation (Shanawany, 1996). The long legs and great speed of the ostrich enable them to cover vast distances in search of water and food (Sauer and Sauer. 1966: Berry and Louw. 1982). For example. Namibian desert ostriches can travel a minimum of 7.7 to 18.5 km per day (Williams et al.. 1993: van Niekerk, 1995).

In a modern ostrich farm. the major products from ostrich are meat, hide and feathers. Ostrich meat is low in fat and its leather is very hard wearing. In South African. 70% of the total income is generated from leather, 20% from meat and only 10% from feather (van Niekerk, 1997a). A 14-month old ostrich can produce 1.4-1.8 kg feathers. 34-41 kg meat and 1.08-1.26 m^2 leather. In recent years. the quality of the skin has been a key factor determining the profitability of the industry. It is well understood that slaughter-age, pecking damaging and other management factors have significant influence on the final skin grade. For example. it is best to slaughter the ostrich when its feathers are in the 'ripe' stage rather than when in the 'blood' stage. as their removal would tend to tear the skin more. leaving a small hole in the skin and degrading the value of the leather. Recently, it has been found that the amount of fat accumulated in the birds and. hence. in the skin has an influence on skin quality. The excess fat resulting from feeding concentrated feeds often makes skinning difficult and contributes to flay cut damage. The excess fat in skins also contributes to uneven uptake of tanning agents and inconsistency in colour of hides. However, under the current production systems. ostriches are fed high protein and high energy diets to achieve maximum growth. despite

Table 1. The length of the digestive tract segments of ostriches (Skadhauge et al., 1984)

Digestive tract segment	Length (cm)	Percentage of total
Esophagus	110	4.6
Proventriculus & gizzard	35	1.5
Duodenum	150	6.3
Jejunum & ileum	700	29.2
Cecum	100 each	8.4
Large intestine	1,200	50
Total	2,395	100

ostriches being adaptable grazers capable of eating a wide variety of grasses, and foraging on bushes and trees. The high feeding levels not only reduce lean meat production and hide quality, but also increase feed costs (Farrell et al., 2000). To develop specific diets and management systems for ostriches to produce high quality products, it is essential to understand the digestive system, the growth patterns, nutrient utilisation efficiency, nutrient requirements and the behaviour of grazing ostriches. This paper reviewed the research progress in the above areas and the implications for commercial ostrich farming.

Digestive systems

The digestive system of the ostrich differs considerably from that of poultry, especially the absence of a crop. The feed passes through the oesophagus directly into the glandular stomach (proventriculus) which is a voluminous structure where mixing and softening of the food with digestive fluids produced by over 300 glands commences, prior to the grinding process done by the gizzard (Figure.1).

There is no distinct anatomical demarcation between the esophagus and proventriculus. The upper part of the esophagus is pouch-like for the accumulation of feed, which moves visibly down the gullet when ostriches swallow. The gizzard (ventriculus) which follows the proventriculus, is a round and very muscular organ which grinds ingested food into small particles. There are small stones and grit in the gizzard that help the mechanical breakdown of food. The gizzard contains pebbles about the size of marbles. The pebbles gradually wear away and pass through the gizzard. Food then passes into the very long small intestine, where the enzymatic digestion of food occurs. The most unique characteristic of the digestive tract of the ostrich is that it contains two large caeca and a remarkably long colon. Digested food remains and moves very slowly through the hind-gut (caeca and colon), which allows exposure of the contents to microbial fermentation for the digestion of fibre. The volatile fatty acids produced through fermentation can be absorbed and utilised as energy.

Length of the digestive tract : It is well known ostriches have a very long digestive tract. 512 cm for small intestine, 94 cm for caecum (each) and 800 cm for colon (Fowler, 1991). Skadhauge et al. (1984) dissected 2 male and 2
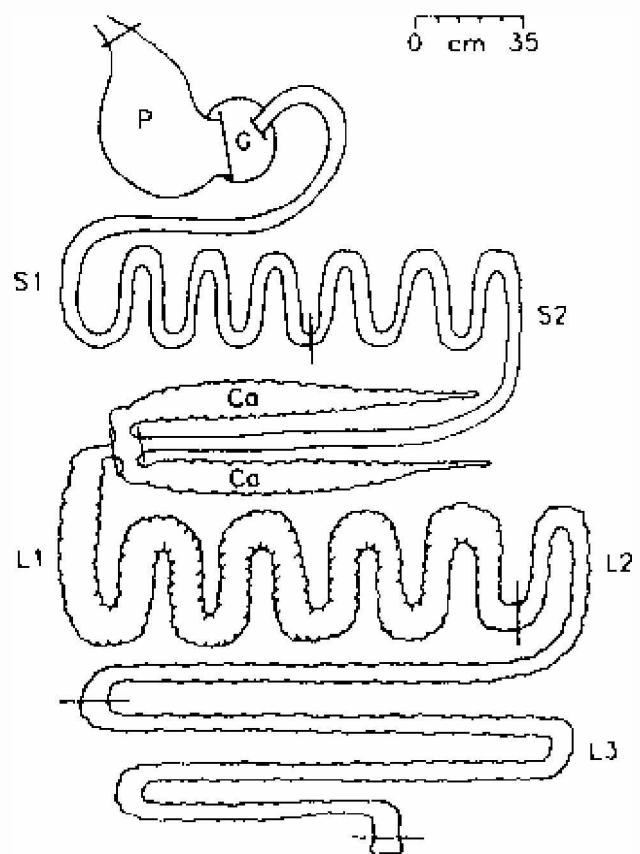

Figure 1. The digestive track of an ostrich chicks at 35 kg live mass (P=proventriculus; G=gizzard; S1=proximal small intestine; S2=distal small intestine; Ca=caeca; L1=proximal colon; L2=mid-colon; L3=distal colon). Source: Swart et al. (1993a)

female adult wild ostriches and found that ostriches have unusually long large intestine which is 50% of the total digestive tract (Table 1).

Swart et al. (1993a) reported that the length of the caeca (paired) varies with the age, being, 101, 106 and 129 cm in ostriches weighing 6.8, 20.7 and 45.8 kg, respectively. A study of the digestive tract of a 30-day-old ostrich chicks revealed for such a young bird the large intestine was over 57% of the length of the combined small and large intestine, indicating the capacity to digest fibre at an early age. This is not surprising considering that dry, arid areas are the ostrich's natural habitat (Farrell, 1997).

In the ostrich, the twin caeca and colon make up two-thirds of the length of the digestive tract which is far in excess of the chicken and other ratites (Table 2). This not only allows for extensive digestion of dietary fibre, but it undoubtedly results in a significant degree of microbial protein and B-vitamin synthesis as in the case of horses (NRC, 1989) and rabbits (NRC, 1977; Cheeke et al., 1987). Although not proven, the *de novo* synthesis of amino acids

Table 2. Comparative lengths (cm) of the intestines of different birds (Angel, 1992)

Section	Ostrich		Emu		Rhea		Chicken	
	Length	%	Length	%	Length	%	Length	%
Small intestine	512	36	243	94	140	61	61	90
Caecum	94	7	6	2	48	21	5	7
Colon	800	57	9	4	40	17	2	3

through microbial fermentation (as in ruminants) is also a strong possibility in ostriches (Smith and Sales, 1995). However, the absorption of amino acid in hindgut is very limited. Based on above, the ostrich is considered a "monogastric" herbivore. This means that ostrich is a simple stomached animal which has developed the ability to utilise roughage (Smith and Sales, 1995). Their elongated hindgut (particularly the caeca) allows the retention of plant fibres for the degradation by gut microflora (Hastings, 1994). The digestion of dietary fibre can provide as much as 76% of the bird's energy requirements (Swart, 1988).

The total length of the intestine, in proportion to body mass, decreased from 160 cm/kg at 6.8 kg liveweight, to 60 cm/kg at 20.7 kg liveweight, and 34 cm/kg at 45.8 kg live mass. The value of 21 cm/kg was reported for adult wild ostriches with a liveweight of 105-131 kg (Skadhauge et al., 1984). It seems more enzymatic digestion occurs in young ostriches. Irrespective of liveweight, the total length of the colon accounts for 52% of the entire length of the intestinal tract (Skadhauge et al., 1984). However, the small intestine contains only 11%, the hindgut (colon and caeca) contains 58% of the total wet digesta contents of the entire intestinal tract (Swart et al., 1993a).

i) Feed selection : It is well known that ostriches eat almost anything, probably because they are strongly attracted by shiny objects, plastic, bone, fragments, metal, small stones, sand and soil (van Niekerk, 1995). However, for organic foods, ostriches are in fact extremely discerning in their eating habits. Ostriches tend to avoid fibrous and lignified grasses, preferring succulent plants (Williams et al., 1993; Milton et al., 1993). Toxic plants and poorly digestible fibrous grasses are also avoided (Williams et al., 1993). Milton et al. (1994) observed feed selection of ostriches in an enclosed environment and found ostriches ingested no toxic plants. They assumed that ostriches could identify these toxic plant species by sight. Although young ostriches will consume insects (Milton et al., 1993), mature birds are largely herbivorous and will rarely consume anything other than plant materials and grit or stone for grinding such food (van Niekerk, 1995).

Ostriches are highly selective in their eating habits (Williams et al., 1993). This is probably because their rounded but sharp bill, good eye-sight and long neck enable them to scan the ground at close range and selectively eat even the smallest of green shoots which they often pluck

from the ground roots (Williams et al., 1993; Milton et al., 1993). Research has shown that free-ranging desert birds are able to select a diet surprisingly high in nutritive value considering the environment (Williams et al., 1993). The average chemical composition of the plants selected by the ostriches, on dry matter basis, was: protein 11.2%, lipids 4.2%, crude fibre 35.2% and ME 8.87 MJ/kg (van Niekerk, 1995). A similar result was reported by Milton et al. (1994), who found that ostriches feeding on natural forage containing 70% water, on a dry mass basis, consumed a diet with 24% fibre, 12% crude protein, 16% ash and 3% lipids, for maintenance.

ii) Feed colour preferences : Ostrich chicks clearly have an acute sense of sight and can distinguish colours. They are attracted by brightly coloured foods such as lucerne leaves, crushed yellow maize or white shell fragments. Ostriches also have the ability to recognise and select even the very smallest shoots of green grass and leaves from shrubs. Their rounded but sharp bill enables even the youngest chicks to nip off the succulent leaves (Williams et al., 1993; Milton et al., 1993).

A colour preference test showed that green was the preferred colour for ostriches. Green colours produced the greatest pecking response which is interesting in view of the herbivorous nature of ostriches. This preference may arise from a disposition towards the ostriches' preferred food in the wild i.e. green foliage (Cooper and Palmer, 1994). White objects appeared to be the second preferred colour and might be related to coprophagy of adult dung, which is usually accompanied by white urate deposits in wild ostriches (Holtzhausen and Kotze, 1990). Once adapted to a particular texture or colour of feed, ostriches are reluctant to change. Milton et al. (1994) found that taste or smell may play a role in determining palatability, because ostriches occasionally dropped plucked plant materials.

Ostrich feeding behaviour

A better understanding of the ostrich behaviour can lead to increased knowledge of developing feeding strategies for ostriches. Although there are many different behaviours (27 recorded by McKeegan and Deeming, 1997) for ostriches, only few are related to feeding. In this paper, only three behaviours of ostriches are reviewed; including 1) foraging (feeding), 2) vigilance and 3) pecking (not feeding).

Foraging : Ostriches spend long periods of time foraging in the wild. This time is increased when ostriches feed in groups. For example, a single bird spends 65% of their time foraging, but up to 85% of their time foraging when in a group of three or four birds. The possible reason for the increase in foraging time is the reduction in the individual ostrich's vigilance time when with companions (Bertram, 1980). The long period of time spent foraging is probably because they need 5-6 kg fresh material mass

Table 3. The time budget (means±SD) for each behaviour of the growing ostriches (after Degen et al., 1989)

Activity	Time consumed (% of 12 active hours)
Sitting	20.4±14
Walking	61.5±12.5
Standing	5.5±3.2
Eating (concentrated feed)	6.6±3.6
Foraging (pecking the ground)	5.0±1.7
Drinking	1.1±0.4

daily for maintenance (containing 70% water) when feeding on the natural forage (Milton et al., 1994).

In farming conditions, ostriches do not spend much time feeding on concentrate feed. The time-activity budget of 5-6 months old growing ostriches that were offered only concentrate feed and maintained on bare ground in four outdoor pens (3×6 m each) was studied by Degen et al. (1989) (Table 3). Ostriches were kept in pairs matched on age and weight. The ostriches were active for about 12 hours during the day and sat for 12 hours at night. These juvenile ostriches spent only 6.6% of their time eating concentrate foods, even when this was the only food available, and 61.5% of their time walking. Despite the fact that no forage was available, they spent 5% of their time pecking at the ground (1957±737 times/day). In this study, ostriches consumed 129.2±25.4g DM earth per day, spent 35.3±13.3 min/day foraging, during which time they pecked the ground 1957 times. Therefore they consumed 3.7±1.4 g DM earth/min foraging and 0.1±0.0 g DM per peck.

Bubier et al. (1996) reported that young ostrich chick (7 to 14 days of age) spent 50.7% of their time foraging and walking (pecking and feeding on ground). These observations appear to reflect a more naturalistic feeding behaviour in the wild where food items are widely spaced and a lot of time would be required to walk to gather food. Furthermore, food presented in bowls was largely ignored whereas food scattered on the floor was readily taken (Bubier et al., 1996; Paxton et al., 1997)

Vigilance : When ostriches forage, some of their time is devoted to vigilance, defined as standing with their necks straight up and looking out for danger. It seems that increased vigilance could reduce the risk of being preyed upon, but reduces the time spent on foraging and therefore a reduced rate of feed intake. An individual bird can spend between 16-48% of its time in vigilance behaviour. This time could be reduced to 4 and 30% when a group of birds foraged (3 or 4 birds) in the wild. The average vigilance time was 34.9% for single birds, 22.9% for birds in groups of two, and 14% for birds in groups of three or four (Bertram, 1980). Bertram (1980) explained that the decline in percentage vigilance time with increase in group size resulted from birds in groups of three or more raising their

Table 4. The different time budget for each behaviour of male and female of ostriches (Ross and Deeming, 1998)

Behaviour	Male	Female	Significance
Stand	28.5±12.6#	15.9±5.7	*
Sit	2.8±8.3	6.0±5.8	NS
Pace	33.2±14.0	16.0±9.1	*
Walk	4.5±3.3	2.3±2.1	NS
Forage	5.3±3.4	25.7±11.1	**
Feeding	13.4±10.6	19.9±7.5	NS
Other	12.4±11.3	14.2±5.6	NS

Mean ± SD, n=9
* p<0.05. **p<0.01.
NS: Not significant difference (Wilcoxon signed rank test)

heads less frequently (49% less often), than single birds.

Males were significantly more vigilant than females. Ross and Deeming (1998) used the mature breeding ostriches to observe their feeding and vigilance behaviour under farming conditions and found that females spent significantly more time foraging than males who spent more time pacing the boundary (Table 4). McKeegan and Deeming (1997) used 26 adult ostriches in breeding condition to study the behaviour of ostriches in a farming environment, and observed that males spent 12% of the time foraging, 8% of the time feeding and 29% of the time pacing in pairs, while 27%, 14% and 12% for females respectively. These differences between males and females are considered to reflect the increased energy requirements of females during the reproductive cycle, and territorial nature of the males in the breeding season (McKeegan and Deeming, 1997). The increase in pacing could also be an indicator that male birds are under greater stress (Glatz, 2001).

Pecking : Pecking behaviour starts soon after hatching and is carried on into adulthood (Lambert et al., 1995, Paxton et al., 1997). Objects (droppings, dung, pellets etc.) on the ground are the most frequent targets of pecking. The pecking activity increases over the first few weeks of age, and is a copied behaviour (Paxton et al., 1997). For example, the tendency to peck on the side of a food tray spread from a single bird (26 days old) to all of the observed chicks in the same pen over the experimental period. It may be beneficial to remove the first chick seen to be habitually pecking at other objects instead of feed to avoid spreading pecking behaviour all over the group. Alternatively feeding behaviour of young chicks can be stimulated by introducing an older chick which has mastered feeding from the food tray. This practice has significant biosecurity risks and keeping young chicks in their own batches is preferable for disease control.

Feed on the floor is more attractive to juvenile chicks than on the tray (Bubier et al., 1996; Paxton et al., 1997). As mentioned earlier, ostriches (5 to 6 months old) in outdoor pens in Israel (Degen et al., 1989) spent over 80% of their

time walking and sitting (61.5% and 20.4% respectively) and only spent 6.6% of their time eating the concentrate feed. One factor affecting feeding from trays appeared to be the density of pellets in the tray. Chicks ate more pellets from partially-empty trays, perhaps because of the increased contrast between the bottom of the tray and the individual pellets compared to full trays where pellets had to be picked from a background of other pellets.

Feather and head pecking were detected by Lambert et al. (1995). Paxton et al. (1997), but data from both sources are limited. The authors found a negative correlation between pecking and growth rate. In other bird species, feather pecking results from misdirected ground pecking behaviour (Glatz. 2000). Pecking in ostriches is associated with malnourished individuals who have poor feeding ability. Nutrition that differs from natural feeding has been shown to encourage feather pecking (Sambraus. 1995). In this study, birds aged 19-46 months were fed *ad libitum* on pellets containing 120 g/kg protein, 300 g/kg crude fibre, 25 g/kg fat and 15 g/kg Ca. Short feeding times were also associated with the feather pecking. However. feather pecking could be avoided if ostriches had a reasonable period to ingest their feed. Over crowding also encourages feather pecking and is especially common during cold and wet weather and in enclosed or sheltered areas. Poor management practices that cause the birds to be stressed also encourage feather pecking (Angel. 1996a).

Growth curve and feed conversion rate

The ostrich growth curve has been reported by Du Preez,
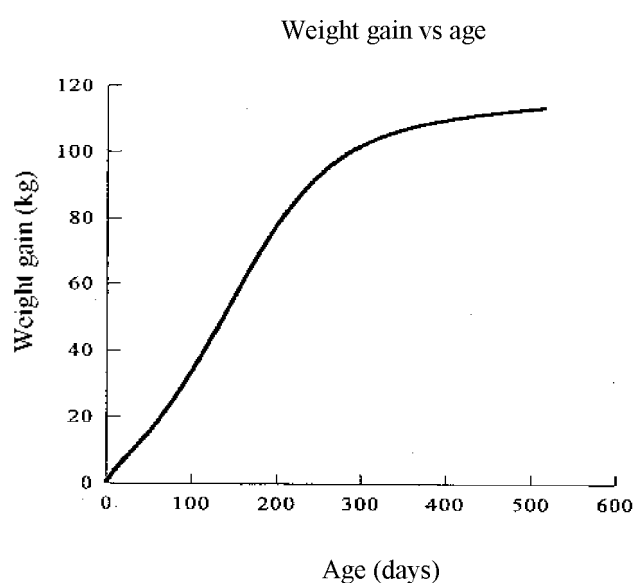
Weight gain vs age

Figure 2. The most recent growth data of South African ostriches from the Little Karoo Agricultural Development Centre. Oudtshoorn. Source: Farrell (1997).

(1991). Du Preez et al. (1992), Degen et al. (1991) and Cilliers et al. (1995). A more recent growth curve (Gompertz equation used to estimate the growth pattern of ostriches) from South Africa, is similar to the above authors' reports, and is shown in Figure 2 (Farrell. 1997).

Ostriches grow fast at a young age and slow down as they age. Degen et al. (1991) reported the ostrich chicks lost 7.6 g/day in the first 6 days, gained 43.4 g/day between 6-14 days, 114 g/day between 14-21 days and 145 g/day between 21-35 days when they weighed 4080 g. The highest average daily gain was 455 g which occurred between 70 and 98 days. A similar result was obtained by Angel (1996b) in Indiana between October 1993 and January 1994, where body weights of ostriches approached 29.6 kg at 90 days of age, when fed a diet containing 22% protein, 3.2% fat. 6.9% fibre, 18.6% NDF, 1.6% Ca. 0.8% available phosphorus and a chick ME calculated at 10 MJ/kg.

The actual mean maximum weight of ostriches was different between the areas. Du Preez et al. (1992) reported that the mature weight were 102.1 kg for males and 98.4 kg for females of Oudtshoorn ostriches. 99.6 kg for males and 94.2 kg for females of Namibian ostriches. However, the difference was also observed in the same area. Cilliers et al. (1995) reported that 115 kg and 114 kg were the maximum weight for males and females respectively for Oudtshoorn ostriches, and the maximum growth rates were achieved at 181 days for males and 199 days for females. However, the maximum growth rates were achieved earlier in Du Preez et al.'s study (1992), at 163 and 175 days for males and females, respectively. This difference is partially a result of the diet quality. For example, ostriches in South Africa are normally slaughtered at 14 months of age at a weight of 95-110 kg; while in USA. body weight of 120-130 kg is common in 12 month old ostriches because in the USA. diets tend to be of higher quality and rearing tends to be intensive rather than extensive as in South Africa (Angel, 1996b).

Feed conversion ratios (FCR) for ostriches are higher than that of poultry species during early growth. According to Cilliers (1995). the following FCRs can be expected for ostriches:

Hatching - 2 months	2:1
2 - 4 months	2:1
4 - 6 months	3.8:1
6 - 10 months	5.5:1
10 - 14 months	10:1

FCR will vary with feed sources and the extent to which the diet meets requirements. The FCR may be 2:1 at the early stages of growth. but this ratio decreases to 5:1 when the body weight reaches about 70 kg (Farrell. 1997). The FCR is close to 10:1 in birds over 10 months (Smith et al.

Table 5. Effect of three forage levels and three protein levels on the performance of ostriches in the 60 to 110 kg weight range (Swart and Kemm, 1985)

Composition of diet (air-dry basis)									
Protein(%)	14			16			18		
Lucerne	67	50	35	67	50	35	67	50	35
ADG	190	204	235	153	129	156	179	240	211
FCR (air-dry)	14	12	10	15	15	13	14	11	10
FCR (DM basis)	12.6	10.8	9.0	13.5	13.5	11.7	12.6	9.9	9.0

FCR, Feed conversion ratio; DM, dry matter; ADG, average daily gain (g/day)

1995). Swart and Kemm (1985) studied the performance of growing ostrich chicks with liveweight between 60 to 110 kg. The diets supplied had three levels of protein (14, 16 and 18%) and three inclusion levels of lucerne (67, 57 and 35%) in a 3×3 factorial experiment design. The best overall performance (235 g/day gain and 10:1 FCR) were obtained with diets supplying 14% protein and 35% lucerne with a calculated poultry ME value of 10.8 MJ ME/kg. The results (Table 5) clearly illustrated that the high FCR was obtained by increasing the lucerne content in the diet. It was not necessary to exceed a protein level of 14% for birds in this liveweight range.

The main reason for the poor feed conversion ratios for older birds is probably due to the poor utilisation of apparent metabolizable energy (AME) by ostriches. Cilliers (1995) reported AME-utilisation efficiencies of 0.414, 0.426 and 0.443 for three groups of ostriches weighing between 70 and 75 kg live weight. The values are markedly lower than values reported in the literature for other species viz. 0.72 for broilers (Chwalibog et al., 1985; Chwalibog, 1991), 0.82 for piglets (Huang et al., 1981). A similar result (0.52 for ostrich chicks with live weights between 0.3 and 1.2 kg) was reported by Chwalibog (1991). Swart et al. (1993b) also reported a conversion efficiency of AME to energy gain of only 0.32 in ostriches between 33 to 42 kg liveweight similar to 0.41 reported by Cilliers et al. (1997b). It is evident that there is a rapid decrease in energy for growth and the ostrich becomes increasingly inefficient with ageing (Farrell. 1997). These suggest that it may be beneficial to reduce the nutrient concentrations in the older bird's diet or to breed a late maturing ostrich with a high mature bodyweight for meat production, or to use the slower growth in older birds for hide production. It is clear that the quality of hides improves as the ostrich approaches its mature bodyweight (100-110 kg) and gives an ideal skin size of about 130 dm^2 (Farrell, 1997; van Niekerk, 1997a). However, van Niekerk (1997a) also stated that a high quality hides are more related to the correct age at slaughter rather than having the correct weight at slaughter in South Africa ostrich farm system. In addition, extra fat in the skin

Table 6. The apparent metabolisable energy-nitrogen corrected (AMEn, MJ/kg air dry basis) value of individual ingredients for ostrich and poultry

Ingredient	Ostrich	Poultry	Data source
Maize	14.3-14.5	14.49	Cilliers et al 1994
Lucerne	8.9	4.49-4.05	,,
Malting barley	14.21	11.06	Cilliers et al 1997a
Oats	12.65	10.48	,,
Triticale	12.60	11.44	,,
Maize	14.89	14.42	,,
Lucerne	8.74	-	,,
Wheat bran	11.7	8.0	Cilliers et al 1999
Saltbush	7.1	-	,,
Saltbush at 30%		3.1	,,
Saltbush at 60%		2.7	,,
Common reed	8.3		,,
Common reed at 30%		2.8	,,
Common reed at 60%		2.8	,,
Lupins		9.6	,,
Lupins at 60%	15.9		,,
Soybean oil cake meal (SBOCM)			,,
At 40%	15.6		,,
At 60%	14.5		,,
At 30%		9.3	,,
At 60%		9.2	,,
Sunflower oil cake meal (SFOCM)	10.5	8.3	,,
Fishmeal at 25%	15.7		,,
Fishmeal at 50%	15.8		,,
Fishmeal at 15%		11.5	,,
Fishmeal at 30%		13.6	,,

Table 7. True apparent metabolisable energy content (MJ/kg air dry basis) of individual ingredients for ostrich and cockerels (Cilliers et al., 1999)

Ingredient	Ostriches	Cockerels
Wheat bran	11.91[a]±0.221	8.55[b]±0.375
Saltbush	7.09[a]±0.238	4.50[b]±0.271
Common reed	8.67[a]±0.337	2.79[b]±0.147
Lupins	14.61[a]±0.340	9.40[b]±0.165
Soybean oil cake meal	13.44[a]±0.173	9.04[b]±0.165
Sunflower oil cake meal	10.79[a]±0.278	8.89[b]±0.494
Fishmeal	15.13[a]±0.315	13.95[b]±0.190

[a, b] Values in the same row with different superscripts differ significantly (p<0.05)

can cause salt curing and bactericidal treatment of hide to be ineffective (Cooper. 2001).

i) Feed digestion and utilisation : Information on the nutritive value of individual ingredients is essential for the development of cost-effective diets for ostriches to produce specific products (e.g. meat. skin). but the source of such information is very limited. Initially most ostrich diets were formulated using data based on poultry diets. Many of these diets have been subsequently modified based on ostrich requirements. but there are still some ostrich diets used that are based mainly on poultry diet statistics. However, the application of poultry data to ostrich is questionable due to the large capability of hindgut fermentation and the significant contribution of end products to the energy requirement for ostriches as demonstrated by Swart (1988). The research conducted by Cilliers et al. (1994, 1997a. b, 1999) further demonstrated the difference in AME content of feed ingredients between ostrich and cockerels (Table 6). The difference between the two species is more significant in the true metabolisable energy content (Table 7). The nitrogen corrected AME (AMEn) values for saltbush, common reed and other ingredients clearly illustrate that ostriches have the ability to metabolise the gross energy in feedstuffs more effectively than poultry. This applies for both the more fibrous materials (e. g. wheat bran. saltbush and common reed) and for protein concentrates (e.g. fishmeal). A recent study in Australia also showed that mean AME values were higher for ostriches than for the cockerels and emu. but similar for diets with pollard or lucerne (Farrell et al.. 2000). Such a species difference is not surprising considering the large chambers of the ostrich hindgut which ensures a longer exposure to microbial digestion. Ramadhani (2000) also found that ostriches have a large capacity to ferment roughage and the amount of total volatile fatty acids in the hindgut content increased with increasing levels of roughage in the diet. but the cellulolytic microorganisms is less in ostrich than in ruminants. More importantly, ostriches recycle their excreta. which consequently increases the dry matter digestibility and AME of diets (Farrell et al.. 2000).

Table 8. True digestibility coefficient of amino acids in a balanced high protein diet (Cilliers et al., 1997b)

Amino acid	Ostrich	Rooster
Threonine	0.831	0.804
Serine	0.849	0.823
Alanine	0.937	0.919
Valine	0.862	0.810
Methionine	0.816	0.776
Phenylalanine	0.809	0.723
Histidine	0.854	0.806
Lysine	0.832	0.755
Isoleucine	0.829	0.817
Tyrosine	0.816	0.764
Arginine	0.780	0.736
Cystine	0.806	0.781
Leucine	0.859	0.825

Amino acid availability is required for accurate diet formulation. but the information on the digestibility of amino acids for ostrich is scarce, presumably due to the cost associated with this type of study. While most ostrich farmers and nutritionists are using data derived from poultry research, Cilliers et al. (1997b) demonstrated a difference between young ostriches and mature roosters in true digestibility of amino acids in a high protein diet (209 g/kg). Amino acid digestibility calculated by regression method ranged from 0.780 to 0.862 for ostriches and 0.723 to 0.825 for roosters (Table 8). The true retention of dietary protein was 0.646 for ostriches and 0.609 for roosters. It is concluded that ostriches are able to use amino acids more efficiently than poultry. The current practice of using digestibility values from poultry in diet formulation for ostriches will underestimate the true availability of amino acids in raw materials, resulting in oversupply of amino acids which may associated with nutrition related problems encountered on commercial farms when ostriches are fed on concentrated feeds.

The feed utilisation efficiency by ostriches is age-dependent. Angel (1993) studied the effect of age on the AME value of feedstuffs. and on fibre and fat digestibility in the ostrich. The feed contained 7.3% fat (soybean oil) and 33.9% neutral detergent fibre (NDF). The AME and the digestibility of fat and NDF increased considerably with age. The ability of the ostrich to digest fibre (NDF) increased linearly up to the age of ten weeks. After ten weeks age it continued to increase. but at a slower rate.

Table 9. The effect of ostrich age on apparent metabolisble energy content and the digestibility of neutral detergent fibre (NDF) and fat in diet (Angel, 1993)

Age	AME	NDF digestibility	Fat digestibility
3 weeks	1,731	6.5	44.1
6 weeks	2,337	27.9	74.3
10 weeks	2,684	51.2	85.7
17 weeks	2,739	58.0	91.1
30months	2,801	61.6	92.9

Table 10. Energy requirement of breeding ostriches for egg production in 0.25 ha. breeding pens (Du Preez, 1991)

	Energy expenditure for maintenance and activity (MJ) for body mass (kg)			Energy (MJ) for production of egg (kg) including shell		
	100	105	110	1.2	1.4	1.6
Maintenance*	13.64	14.12	14.60			
Activity	1.37	1.41	1.46			
Egg lipid				2.30	2.68	3.07
Egg protein				3.58	4.18	4.77
Shell** (18% of egg mass)				0.26	0.30	0.35
Total	15.01	15.53	16.06	6.14	7.16	8.19

* 1.63 Pm0.73 where Pm = protein mass in body at maturity (Emmans and Fisher, 1986)
** 1.2 MJ per kg shell formed.

Table 11. Requirements of some amino acids of breeding ostriches in full production (Du Preez, 1991)

	For maintenance of body mass (kg)			For egg production including shell (kg)		
	100	105	110	1.2	1.4	1.6
Protein (g)	67	69	72	119	138	158
Amino acids (g) *						
Arginine	5.70	5.87	6.12	3.56	4.15	4.74
Lysine	5.78	5.95	6.21	6.41	7.48	8.55
Methionine	1.86	1.90	2.00	2.67	3.10	3.56
Histidine	2.54	2.61	2.73	1.91	2.20	2.50
Threonine	3.54	3.64	3.80	6.85	8.00	9.13
Valine	4.32	4.46	4.65	5.50	6.40	7.30
Isoleucine	3.50	3.60	3.75	4.55	5.30	6.10
Leucine	6.90	7.14	7.45	9.00	10.50	12.00
Tyrosine	2.33	2.40	2.50	3.70	4.30	4.90
Phenylalanine	3.82	3.90	4.10	4.06	4.67	5.30
Cystine	0.89	0.92	0.96	0.99	1.15	1.32
Tryptophan	0.73	0.75	0.78	1.20	1.45	1.64

* Quantities of dietary amino acids required per day in grams.

reaching a plateau at 17 weeks (Table 9). This suggests that when poultry AME values are used to formulate diets for adult ostriches the actual AME value of the feed for ostriches could be underestimated by as much as 41% and this AME underestimation is evident beginning at 6 weeks of age. However. Cilliers et al. (1998) did not find any difference in the AME values of lucerne and barley for adult (110-112 kg) and growing (50-60 kg) ostriches.

Although the above literature suggests there are differences in the nutrient utilisation efficiency between ostriches and poultry, and more feed ingredients need to be assessed. the costs for feed evaluation is a key limiting factor for the ostrich industry to support large scale feed evaluation, especially in these countries like Australia where the ostrich industry has not been well established. Thus it is vital to develop a rapid in vitro assay which can be used to predict the nutritive value of feed ingredients for ostrich. Ramadhani (2000) examined the potential of using hindgut liquor of the ostrich to estimate the digestibility of diet. He revealed that the in vitro digestibility using hindgut liquor of ostrich is lower than that obtained with rumen fluid of steers. However, the author did not validate the in vitro method using the in vivo digestibility of ostrich. If this in vitro approach is possible for ostrich feed evaluation. more feed ingredients. especially the local unique feed sources can be evaluated for the inclusion in the ostrich diet at a low cost.

Nutrient requirement of ostriches

Breeding birds : There are many myths on the nutrient requirement of ostriches. The complexity of the nutrient requirements for breeding birds is still not well understood. Many gauge the nutritional status of the breeding birds by the number of eggs produced. quality of feathers and the general vigour of the birds. The nutritional status of the breeders is also reflected by fertility. hatchability and nutritional status of the chicks in the early stages of their lives. Nel (1991 cited by van Niekerk, 1997) reported that feeding ostriches *ad libitum* had a deleterious effect on fertility, and Du Preez (1991) recommended energy and amino acid requirements for laying birds of three different body weights and egg sizes (Tables 10 and 11), but limited information is available on actual nutrient requirements for breeding ostriches. The mineral and vitamin requirements for breeding ostriches have not been well defined, but Cillers and van Schalkwyk (1994) recommended the total Ca. available P and total Na for layer diets to be 2.0-2.5%. 0.35-0.40% and 0.15-0.25%, respectively. van Niekerk (1995) also suggested that calcium levels traditionally recommended for ostrich layer diets are lower than those

Table 12. Calculated TMEn requirements for maintenance and growth in ostriches at various growth intervals (Cilliers, 2000)

Age (day)	Body mass (kg)	Body mass for period (kg)	Feed intake (kg/bird)	Carcass energy gain (MJ/day)	Energy for growth (MJ/day)	Energy for maintenance (MJ/day)	Total (MJ/day)	Diet level TMEn (MJ/kg)
30	3.3	1.8	0.25	2.400	2.671	0.673	3.34	13.6
60	9.1	6.6	0.49	5.333	5.938	1.757	7.70	15.7
90	16.6	14.6	0.75	6.475	7.211	3.182	10.39	13.9
120	25.0	23.6	0.91	6.856	7.635	4.547	12.18	13.4
150	36.2	33.6	1.35	8.380	9.332	5.925	15.26	11.3
180	47.9	45.4	1.65	9.599	10.689	7.429	18.12	11.0
210	58.2	57.5	1.81	8.570	9.544	8.869	18.41	10.2
240	67.4	68.1	1.90	7.540	8.398	10.077	18.48	9.7
270	75.8	77.6	1.95	6.970	7.761	11.122	18.88	9.7
300	83.7	86.5	2.00	6.551	7.296	12.064	19.36	9.7
330	88.6	93.6	2.40	4.036	4.500	12.791	17.29	7.2
360	91.9	96.0	2.45	2.740	3.054	13.246	16.30	6.7
390	95.2	101.6	2.50	2.740	3.054	13.609	16.66	6.7
420	98.4	105.2	2.50	2.606	2.960	13.964	16.92	6.8
450	101.2	108.4	2.50	2.265	2.545	14.287	16.83	6.7
480	103.2	111.1	2.50	1.752	1.951	14.548	16.50	6.6
510	105.1	113.2	2.50	1.447	1.612	14.754	16.37	6.5
540	106.7	115.0	2.50	1.371	1.527	14.934	16.46	6.6
570	109.1	117.2	2.50	1.961	2.206	15.148	17.35	6.9
600	110.7	119.4	2.50	1.295	1.442	15.356	16.80	6.7

used in commercial poultry diets since ostriches lay only every second day with fairly regular pauses. Until more research data becomes available, the recommendation by Cilliers and van Schalkwyk (1994) can be used as a guideline to supplement the diet of breeding birds (Table 15).

Growing birds : More emphasis has to be placed on the nutritional requirements of the growing ostriches due to their very rapid growth rate, which increases the chances of nutrient imbalances or deficiencies. In both commercial and

Table 13. Maintenance requirement, retention and net utilisation efficiency of protein and amino acids in ostriches (calculated according to mean empty body weight (EBW) of 65 kg for the period (Cilliers, 2000)

Nutrient	Maintenance mg/EBW, kg/day	Retention rates mg/EBW, kg/day	Net efficiency
Protein	678	3,276	
Threonine	57	60	0.710
Serine	53	56	0.615
Alanine	86	102	0.968
Valine	65	72	0.702
Methionine	38	33	0.780
Phenylalanine	68	74	0.654
Histidine	47	45	0.877
Lysine	91	109	0.733
Isoleucine	60	63	0.682
Tyrosine	51	51	0.904
Arginine	96	118	0.948
Cystine	21	19	0.569
Leucine	91	111	0.569

non-commercial countries. the time for growing ostriches to reach market size is vital for the industry and high energy and protein diets have been designed to achieve a rapid growth. Under most situations. most nutritional problems arise in the first twelve weeks of a chick's life (Dolensek and Bruning. 1978). However, the nutrient requirements have not been determined on growing ostriches. Up to 1996. diets have been formulated on the basis of the requirements for other species in conjunction with information obtained by observation (Angel, 1996b). although researchers in South Africa conducted a number of experiments to estimate the nutrient requirements for growing ostriches during late 90's. In 1985. Swart and Kemm reported that the best performance was obtained at a lower protein level (14%) and higher energy level (10.8 MJ ME/kg - poultry value) for birds with a body weight from 60 to 110 kg. The high level of dietary protein is not justified for ostriches kept in a zoo environment according to Reddacliff (1981) although the author did not consider requirements for commercially grown ostriches and 16% crude protein is adequate for ostriches considering the natural food types consumed. Gandini et al. (1986) investigated the nutrition of ostrich chicks on four isoenergetic diets containing either 14%. 16%. 18% or 20% protein. The growth rates of the 20%. 18% and 16% protein groups were all similar at 9,134 g. 8,754 g and 8,440 g. respectively. but higher than the 14% group at 5438 g. The most efficient group was the 18% protein treatment. with a FCR of 1.65.

Cilliers (1995) determined the TMEn and effective energy (EE) and the results were extrapolated to estimate

Table 14. Ca, P and Na specifications for grower and maintenance diets for ostriches (Cilliers and van Schalkwyk, 1994)

Diet type	Total Ca (%)	Available P (%)	Total Na (%)
Prestarter, starter and grower	1.2-1.5	0.40-0.45	0.20-0.25
Finisher and post finisher	0.9-1.0	0.32-0.36	0.15-0.30
Maintenance	0.9-1.0	0.32-0.36	0.15-0.30

requirements from day old to 20 months of age. He found that TMEn required for maintenance was 0.425 MJ/empty body weight (EBW), $kg^{0.75}$/day or 7.96 MJ/day. Utilisation efficiency for TMEn was 0.414±0.006 (MJ/EBW, $kg^{0.75}$/day) and digestible protein requirement for maintenance was 0.678±0.027 g/EBW, $kg^{0.75}$/day. Net utilisation efficiencies for digestible amino acids varied between 0.948±0.025 for slow turnover amino acids (arginine) and 0.569±0.015 for the fast turnover amino acids (cystine) with a mean value of 0.747. Based on his research outcomes, Cilliers (2000 unpublished) recommended energy, protein and amino acids requirements by growing ostriches for growth and maintenance at different ages (Table 12 & 13) assuming that body composition and the efficiency of nutrient utilisation is constant at different maturity stages. However, these assumptions might not be true in practice, thus the data listed in the following tables are only guidelines for feeding ostriches.

Up to now, no rigorous experiments have been carried out to estimate the actual mineral requirements. It is believed that a major problem in the feeding of ostriches is that Ca is very often overfed and this could lead to depressed uptake of zinc and manganese. Manganese deficiency has been implicated in the deformed leg syndrome and more specifically perosis. It is also well known that a manganese deficiency can lead to slipped tendons as experienced in broiler chickens. Zinc deficiency may lead to limb deformities, enlarged joints and thickening of the skin of the feet and legs. Selenium deficiencies have also being diagnosed in young ostriches and leads to lameness simulating "white muscle disease" in lambs. These ostriches responded well to Vitamin E and selenium supplementation. Ostriches are, however, very sensitive to injectable selenium and feed supplementation is recommended. Based on South African experience, Cilliers and van Schalkwyk (1994) suggested the Ca, P and Na specifications (Table 14), trace element and vitamin supplementation guidelines in the different types of ostrich diets (Table 15). However, most recommendations are based on the prevention of deformities such as perosis, slipped-tendon, bow-leg, bent-leg and straddle-leg caused by overfeeding or deficiencies of minerals (Ca, P, Se, Zn, Mg) and vitamins (VE, VD3) (Flieg, 1973; Dolensek and

Table 15. Trace element and vitamin supplementation in total diets for ostriches (Cilliers and van Schalkwyk, 1994)

Nutrients	Unit	Grower diets birth-6 months (/1,000 kg)	Grower and finisher diets 6 months-slaughter (/1,000 kg)	Layer diets (/1,000 kg)
V A	IU	12,000,000	9,000,000	15,000,000
V D3	IU	3,000,000	2,000,000	2,500,000
V E	IU	40,000	10,000	30,000
V K3	g	3	2	3
V B1	g	3	1	2
V B2	g	8	5	8
Niacin	g	60	50	45
Calc. Panth. A	g	14	8	18
V B12	mg	100	10	100
V B6	g	4	3	4
Choline Chloride	g	500	150	500
Folic acid	g	2	1	1
Biotin	mg	200	10	100
EndoxⓇ	g	100	-	100
Mg	g	50	-	40
Mn	g	120	80	120
Zn	g	80	50	90
Cu	g	15	15	15
I	g	0.5	1	1
Co	g	0.1	0.3	0.1
Fe	g	35	20	35
Se	g	0.3	0.15	0.3

Bruning, 1978; van Heerden et al., 1983; Gandini et al., 1986; Stewart, 1989b).

Utilisation of dietary fibre

As mentioned early, ostriches are almost exclusively herbivorous with a well developed hindgut. The large intestine and caeca of the ostrich provide a suitable environment (pH, 6.9-7.3) for microorganisms to ferment dietary fibre (Swart et al., 1993d). Many species of anaerobic fermentative bacteria are present, but no ciliate protozoa have been found. Like ruminants, the main fermentation product is volatile fatty acids (VFA), mainly including acetate, propionate and butyrate. Interestingly, the high concentrations of total VFA was found in the proventriculus and gizzard (139.3 and 158.8 mM respectively), but it is unknown if this is from microbial fermentation or from other sources. The concentration decreased to 65-78 mM in the small intestine, probably because the absorption of VFA has occurred and no VFA is produced in the small intestine. However, the VFA concentration increased in caeca (140 mM) and in colon (171 to 195 mM) (Swart et al., 1993a). A relatively large amount of acetate was found in the digestive tracts of ostriches and was the only VFA presented in the

Table 16. Nutrient digestibility of the experiment diet fed to ostriches of different live masses (Swart et al., 1993c)

Measurement	Liveweight range (kg)		
	5-10 (n=6)	15-18 (n=5)	42-50 (n=4)
Feed intake			
DM (g/kg)	556.1^a±21.3*	745.2^b±31.8	947.7^c±148
ME (MJ/day)	7.15	9.15	11.22
Digestibility (%)			
DM	74.9±1.7	71.7±0.5	67.2±1.8
NDF (cell wall)	52.4^a±2.2	43.7^b±0.6	45.6$^{a, b}$±3.2
Hemicellulose	69.3^a±1.0	62.7^b±0.4	66.2^a±3.8
ADF	35.8±3.4	26.4±0.8	39.3±3.2
Cellulose	42.1^a±2.7	38.2^b±0.6	35.1^{a,b}±2.6
Lignin	11.9±5.7	4.3±5.5	8.1±5.8
Energy digestion			
ME (MJ/kg)	12.85^a±0.2	12.28^b±0.1	11.84^{a,b}±0.6
ME (% of GE)	78.9±1.3	75.4±0.5	72.7±2.1

* values are means±SE; DM, dry matter; ME, metabolisable energy; NDF, neutral detergent fibre; ADF, acid detergent fibre; GE, gross energy.
$^{a-c}$ Denote significance of differences in rows (p<0.05)

proventriculus, gizzard and small intestine, lesser concentrations of propionate and butyrate, and trace amounts of isobutyrate, isovalerate, and valerate were found in hindgut (Swart et al., 1993a). The high proportion of acetate and low proportion of propionate are indicative of fermentation of fibre or material high in plant cell walls (Hungate, 1984; Prins et al., 1984).

The energy contributed from VFAs could provide 52%-76% of the daily intake of ME to the host (Swart et al., 1993b). This is similar to the value (60-70%) for ruminants (Bergman et al., 1965). Swart (1988) also found that dietary fibre can provide as much as 76% of the bird's energy requirements. Swart et al. (1993c) used 15 ostrich chicks, live weight ranging from 5-50 kg, to determine the fibre digestibility and retention time of digesta. The digestibility coefficients for NDF, hemicellulose and cellulose were 47%, 66% and 38%, respectively regardless of liveweight. The retention time was from 20.9 to 75.7 h, average 40.1 h. The slow passage of feed through the hindgut allows good microbial fermentation of plant fibre (Swart et al., 1993c).

Ratites are precocial birds that produce young capable of moving and foraging for feed within the first 48 hours after hatching (Angel, 1996b). Ostriches are able to digest fibre at an early age. This is not surprising considering the natural feeding habit of ostriches. The forage with high fibre needs to be fermented as an energy source for the host. Swart et al. (1993c) measured the fibre digestibility using three different liveweights and ages from 42 to 210 days of ostriches. The young birds can digest the dietary fibre with the same capacity or greater as older birds do (Table 16). However, Angel (1993) reported that the digestibility of fibre for ostriches was influenced by age.

Potential fibre sources for ostriches

It has been proven that low-fibre, high energy/protein diets can lead to excessively fast growth and precipitate leg problems (Gandini et al., 1986; Stewart, 1989b; van Niekerk, 1997b). The conditions are variously known as perosis, slipped-tendon, bow-leg, bent-leg and straddle-leg. Quite fat ostriches with a "goose-stepping" gait were observed when fed all-grain diets (Black, 1997). Other problems (e.g. lower hatchability, reduced egg quality etc.) may have also been present on some Australian farms. It is assumed that these disorders result from overfeeding and consequent excessive growth (Gandini et al., 1986; Stewart, 1989b), deficiencies of calcium, phosphorus and vitamin D3 (Gandini et al., 1986), vitamin E, selenium (Dolensek and Bruning, 1978; van Heerden et al., 1983), methionine, choline (Flieg, 1973), zinc or manganese (Gandini et al., 1986; Stewart, 1989b). However, Stewart (1989b) suggested that a decline in protein intake and increased exercise can cure the problem if it is detected early.

Normally, the newly hatched ostrich chicks are fed a high protein diet. This can result in a rapid growth of the chick and frequently results, at 2 to 6 weeks of age, in the development of an osteodystrophy whereby there is lateral rotation of the distal tibia. The presence of large cones of embryonic cartilage in the tibio-tarsal bones of 3-week-old ratite birds is probably a normal phenomenon. Awareness of this feature is necessary for the correct differential diagnosis of the prevalent musculo-skeletal disorders of ratite birds (Reece and Butler, 1984). An eight-week study (Gandini et al., 1986) with 20 ostrich chicks of 8-10 days old conducted in South Africa found that during the experimental period, five ostrich chicks developed leg abnormalities (between 6 and 7 weeks old). Three were from the group fed 200 g protein per kg diet, one each from 160 and 140 g protein per kg diet. However, leg abnormalities are more related to dietary imbalance than inappropriate protein levels. It seems unlikely that ostrich would require higher dietary concentrations of calcium than are found in their natural feedstuffs or that are required for growth of chickens and turkeys (NRC, 1984). It is just as likely that limited exercise and the rapid rates of soft tissue growth (particularly on diets containing 200 g protein /kg) promoted by these low-fibre, energy-dense diets was responsible (Ullrey and Allen, 1996). This indicates certain amount of fibre is required in the chicks (2-10 weeks) diets for a health growth.

Lucerne : Lucerne is used as a dietary ingredient or for grazing for ostriches due to its relatively higher crude protein content (18%) and fibre (30%), resulting higher AMEn (8.9 MJ/kg) and dry matter digestibility (DMD: 50.1%) for adult ostriches. Lucerne is high in carotene and lime (Holtzhausen and Kotze, 1990). Although lucerne is the most desired forages for all age of ostriches, it is expensive and is difficult to grow in the dry areas in

southern Australia because of the requirement of good soil and irrigation.

Wheat Bran : Wheat bran, a by-product of flour manufacturing, is rich in insoluble non-starch polysaccharides (NSP). It contains 18% crude protein and 13% crude fibre. Cilliers et al. (1994) concluded that wheat bran could be a useful alternative for lucerne in ostrich diet. The TMEn of sole wheat bran for adult male ostriches of 2 years old was 11.91 MJ/kg (air dry basis).

Wheat pollard, Rhodes grass and wheat straw : Wheat straw is poor in nutritional quality with a crude protein being only 3.0% and crude fibre being as high as 42%. Rhodes grass at late vegetative stage contains 11.8% ash, 12.5% crude protein and 31.89% ADF on a dry matter basis. However, these roughage sources can replace about 20% lucerne meal in the ostrich (10 kg liveweight) without affecting the bird's performance (Farrell et al., 2000). In Farrell's study the DMD of wheat pollard, Rhodes grass and the wheat straw diets were 93%, 85% and 84%, respectively. The corresponding values for AME were 17.82, 16.13 and 16.26 MJ/kg DM (by replacing 200 g/kg basal diet). As these roughages are poor in quality, a high proportion of these roughage in the diet could cause a detrimental effect on the performance of ostriches.

Saltbush and Common reed : Common reed at bud stage just before bloom has a crude protein content of 10.5%. Drought-resistant fodders, such as saltbush and common reed could be alternatives for lucerne for ostriches as the TMEn of saltbush and common reed for mature ostriches were 7.09 and 8.67 MJ/kg (Cilliers et al., 1999). However, saltbush usually has a high salt content in the leaves and a high ash content of 31.5% at the early vegetative stage. Whether the high salt content has a negative effect on ostrich performance is unknown, but such information would be of significance to the ostrich industry, especially in southern Australia where salinity is a great threat. Ostriches may potentially ingest significant amount of salt from pastures in these salt-affected regions and salty water in the dams. The salt tolerance of ostriches and the detrimental effect of salt on shell quality and meat quality need to be assessed.

Pasture and silage : Ostriches in natural rangelands graze green annual grasses and forbs when available. Pasture can make a substantial contribution to the nutrient requirements of ostriches, but there is a need to develop a suitable concentrate supplement to a specific pasture type during certain period of the year for a specific product. Two grazing trials were conducted by Farrell et al. (2000) to determine the forage intake for ostriches grazing Rhodes grass, Kikuyu grass and white clover pastures. In the first experiment, pasture intake for ostriches (50 kg liveweight), with concentrate supplementation of 60, 70, 80 and 100% of appetite, ranged from 648-858 g/day, and daily gain

ranged from 248 to 299 g during 84 days. In the second experiment, the pasture intake for ostriches (37 kg liveweight) ranged from 185 to 315 g/day, and daily gain ranged from 180 to 408 g with concentrate supplementation 50, 75 and 100% of appetite. Generally, reducing the concentrate supplementation (not lower than 70%) increased the pasture intake regardless of the quality of the pasture. However, at the same level of supplementation, forage intake is usually higher on high quality than on low quality pastures.

The use of silage as source of roughage for ostriches has tremendous potential for the ostrich industry. The study by Cilliers et al. (1998) demonstrated the potential of maize silage as a source of nutrient supply for growing ostriches (50-70 kg). In this 40-day period trial, the average daily gain of birds fed on silage-conentrate at 1.25 kg/day/bird was 0.353 kg/day which was 25% lower than the control group fed on balanced diet.

In summary, poor quality fibre sources such as wheat straw can replace 20% of lucerne meal without reducing the production of ostriches. The high quality of pasture can contribute a significant amount of nutrient needs for ostriches. This suggests the possibility to achieve maximum production with least cost by properly using roughage or pasture sources with a suitable concentrate supplementation for ostriches.

CONCLUSION

The ostrich industry is new and has not been well established in Australia and some Asian countries. The success of the industry is largely dependent on the quality of the products, especially the hide which has great market in Japan, Korea and other countries. To meet the market demands, it is essential to develop specific diets and feeding regimes using local feed resources for particular products under different production systems (feedlot, grazing) based on the growth pattern of ostrich. To achieve this target, ostrich producers and nutritionists need information on nutritive value of feed ingredients, nutrient requirements of ostriches, and forage intake of ostriches under grazing conditions. However, there are many gaps in our knowledge of ostrich nutrition and the following areas require further research.

Nutritive value of feed ingredients

Nutritive value of feed ingredients is essential for the development of ostrich diet in the feedlot situation or supplementary feeding strategies under grazing conditions. Currently there is not much information available for the ostrich industry in Australia. While South African researchers evaluated a number of feed ingredients, most ostrich farmers are using data generated from poultry for

their diet formulation. It is clear that a difference in digestion and utilisation exists between poultry and ostriches, and between young and old ostriches, due to the difference in fermentation capability. Thus it is necessary to evaluate feeds commonly used by both young and adult birds.

Feed evaluation using the traditional method is expensive for all livestock species. This is particularly true for ostriches in Australia where this industry has not been well developed. Thus the rapid and low-cost *in vitro* methodology for feed evaluation will be very attractive to the industry and warrants further research and development.

Nutrient requirements of ostriches

There are many gaps in our understanding of the nutrient requirement of ostriches. While Cilliers (1995) and Cilliers et al. (1998) conducted a number of experiments to define the energy, protein and amino acid requirements of growing birds, these data are derived from very limited number of birds and the direct application to Australian environment is questionable. Because of the complicated interactions between minerals and vitamins, it is difficult to assess the actual requirement of ostriches. Given the limited funds for research and development, it is essential for the industry to focus on the definition of the energy, protein and amino acid requirement under different farming systems (e.g. feedlot, grazing).

Development of diets for specific products

Ostriches have a similar growth curve to other livestock species, indicated by a rapid growth in the early stage and a poor feed conversion ratio in the late stage. High energy and high protein diets have been traditionally fed to achieve rapid growth and high meat quality, but hides are of more value than meat. There is a need to utilise diets to reduce fat in the live bird and produce high quality skins because the removal of excess fat during skinning (from feeding concentrated feeds) often results in flay cut damage contributing to uneven uptake of tanning agents and inconsistency in colour of hides. Currently the Rural Industry Research and Development Corporation (RIRDC) is funding a project to design cheap fibrous diets for ostriches to produce high quality hide by reducing fat deposition during the late growing stage. However, the ostrich industry also requires a diet that can be fed to maximise the meat production and meet market fluctuation.

Grazing management of ostriches in a crop-pasture rotation system

Traditionally most ostriches are fed intensively with high energy and protein feed. Under this system, mortality caused by diseases are significantly high and feed cost accounts for over 70% of the production cost. Experience from a few ostrich farmers in Australia and overseas suggest that grazing ostriches in paddocks improves the profitability by reducing mortality and feed cost. A project being conducted by South Australian Research and Development Institute (SARDI) is examining the potential of incorporating ostriches into a crop-pasture rotation systems. Within this project, a supplementary diet will be developed, the use of an innovative pasture, crop and ostrich rotation system will be established, and dry-land pastures as alternative to lucerne for ostrich grazing will be evaluated. However, the development of supplementary diet is complicated by the forage intake of grazing birds which is not easy to measure in the field. More importantly, the sustainability of the grazing systems needs to be assessed.

Grazing ostrich in salt affected areas in Australia

It has been well understood that ostriches can graze grass, berries, succulents, seeds and leaves of trees and bushes, and prefer arid or semi-desert terrain. Ostriches drink large volumes of water in hot weather and have been able to adapt living in arid climates by being able to travel long distances to find water. There is some reabsorption of water in the copradeum or cloaca but this is not as significant as in emus. In Australia, the arid and semi arid regions cover 70 to 75% of the continent (Ffolliott et al., 1995), rainfall is variable and of low intensity. Typically the land is flat and only wide, shallow storage of water is possible. The high evaporation rates result from high radiation, high temperature and low humidity, especially in summer. Water quality, especially high concentrations of salts present some of the greatest limitations for the use of water by livestock (Anon, 1976; Goodspeed and Winkworth, 1978; Ru et al., 2000).

The vegetation of large areas of arid and semi-arid Australia is dominated by species of the genera *Atriplex* (saltbushes) and *Kochia* (bluebushes). These shrubs are invaluable feed resources in summer. While the nutritional value of these bushes are evaluated by a number of researchers, the high salt concentration in leaves may be a disadvantage to animal production, especially over drought periods. However, farmers need information on salt tolerance of ostrich to optimise the production system and eliminate animal ethics concerns.

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