Nutrition of Ratites: Comparison of Emu and Ostrich Requirements

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Summary

While there is a reasonable volume of literature available on the physiology and ecology of the emu and ostrich there is very limited published information on their specific nutrient requirements. This paper attempts to summarise the information available and draw comparisons. The ostrich has been shown to utilise plant fibre with an efficiency equivalent to mammalian herbivores. The emu has a much simpler gut than the ostrich and its ability to digest similar quantities of fibre is yet to be proven. Season has a marked effect on the appetite and growth of emus and this presents unique problems for their adaptation to a farmed animal. Available information suggests that emus and ostriches convert dietary nutrient intake to liveweight gain with a similar efficiency.

The commercial farming of emus in Australia was officially sanctioned by the Western Australian Government in 1987 and it is now a national industry with 1300 farmers holding 84,000 birds and a forecast production for the 1995/96 season of 116,000 chicks (Australian Emu 1995). The industry is many times bigger in America and an estimate that 800,000 chicks will be produced during their next hatching season which commences in December 1995 is considered to be conservative (Frapple and O'Malley 1994). Significant flocks are also known to exist in Europe and China.

Ostrich production has long been associated with South Africa but there has been a rapid world wide increase in ostrich production since 1985 and a recent global production forecast made for the Australian Ostrich Association (McKinna et al., 1994) estimated the 1995 population to be 863,000 birds held on 7,468 farms. While the highest estimate is for South Africa (575,000), America (182,000), Israel (20,000) and Australia (36,000) have sizeable populations.

Despite both industries being heavily reliant on total mix diets there is a lack of reliable estimates of specific nutrient requirements and most rations have been formulated on limited data or by the extrapolation of values determined for poultry. In general, this has resulted in the development of diets which have been in excess of the birds true requirements. This situation is likely to continue until defmitive work on the bird's ability to derive, energy, protein and minerals from available feed sources and the birds' growth and egg production response to a range of intakes of dietary energy and protein is published.

Information for ostriches is now becoming available but there is little published work for emus, and the wild and difficult nature of the bird will mean that reliable information on digestibility and metabolism will be difficult to derive (Maloney and Dawson, 1993).

Food selection in the wild

Davies (1978) examined what the emu eats in its natural environment and found they feed on a great variety of fruits, seeds, flowers, insects and green herbage of annual and perennial plants. Shrubs provided most of the food in spring and autumn (September to March), annuals in the autumn and winter (April to August) and insects are taken whenever they are in abundance, usually in autumn and spring. The selection did not include dried herbage or grass nor the mature leaves of shrubs and implied the harvesting of a nutrient rich source of food. Shrubs provided a reliable supply of food in summer but annuals often produced little in the autumn and emus were often faced with a food shortage during the autumn - winter period.

Milton et al. (1994) studied the food selection of ostriches in southern African savanna, desert grassland and shrubland, and Mediterranean shrubland. Ostriches fed on green annual grasses and forbs when available. When they were not available they consumed leaves, flowers and fruits from succulents and woody plants. Dead or woody material and animal matter (other than bone) was absent from their diet. For maintenance they needed to consume 5 - 6 kg of fresh mass daily containing 70% water (on a dry matter basis, 24% fibre, 12% crude protein, 16% ash, 3% lipid).

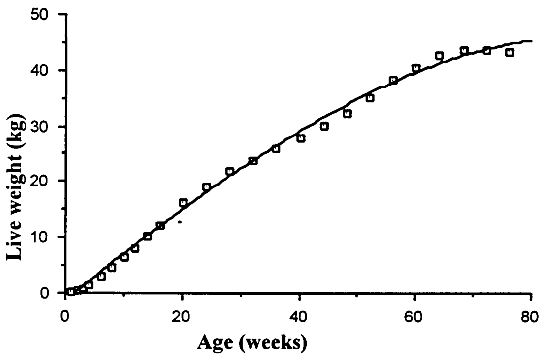
These studies suggest that both species are well adapted to a herbivorous diet but their ability to graze over large areas allows the selection of the better quality food items. Emus appear to eat more fruits, seeds and insects than ostrich and will eat these in preference to green herbage.

Growth

Du Preez et al., (1992) published results on fitting a Gompertz model to growth performance data for ostriches from different localities in Southern Africa. Smith et al.(1995) reports that Cilliers (1995) verified the results and suggested minor alterations to the growth parameters. The estimated mean mature (14 months) liveweights were 119.2 kg for males and 122. 3 kg for females and the maximum rate of growth occurred at 163 - 175 days of age (Du Preez et al., 1992; Smith et al., 1995).

A Gompertz function has been fitted to growth data recorded on a number of flocks grown at the Medina Research station but it does not represent the data well as there are significant non random differences between the data and the fitted curve.

Figure 1 Typical Emu Growth Curve



The deviation of the observed data is caused by an observed seasonal decline in the rate of increase in feed intake and a slowing in growth after the maximum rate of gain of 120 - 130 g/b/d has been reached at around 25 weeks of age (Figures 2 & 3).

Seasonal effects

Season has a marked effect on appetite and growth and maturing and older birds show a marked decline in food intake in mid December each year. Body weight plateaus from December to February before commencing to decline at a rate of 0.7 to 1 .0 kilogram per week until late July when appetite rises sharply and lost body reserves are replaced. In general terms females are 1.5 kilograms heavier than males but males carry a higher weight of fat. Emus are therefore extremely well adapted to their natural environment. Reserves of body fat lost during winter are replaced quickly by an increase in appetite in the early spring and summer months, when the availability of natural feed sources are highest. (Davies, 1978) They then maintain liveweight for a few months before loosing appetite to develop an energy deficient diet for the winter breeding season, when natural food sources are scarce.

A rapid build up of storage fat was confirmed by a sequential slaughter of groups of 20 emus from 20 to 70 weeks of age. Figure 4. summarises the apparent rate of liveweight, muscle and fat gain based on the break down of the carcases for their commercial products.

Figure 4

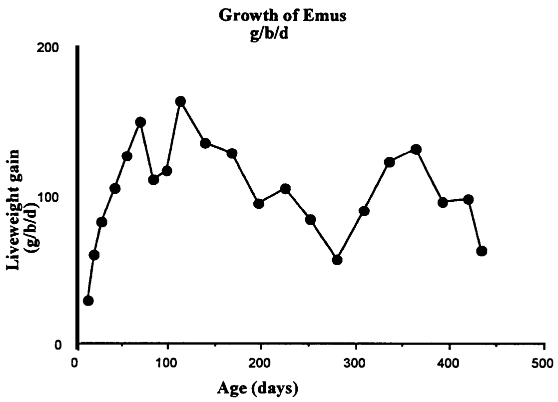


Figure 2

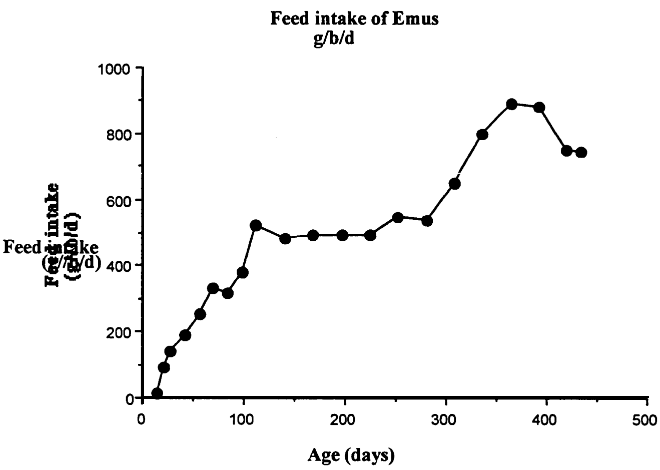
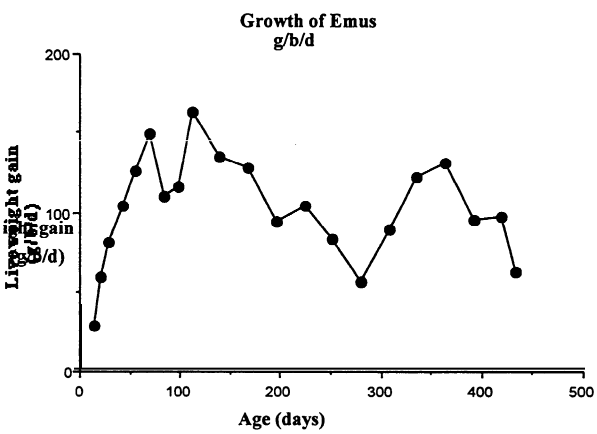


Figure 3.



Digestion

The anatomy and function of the digestive tract of the emu and ostrich is well described in the literature (Herd and Dawson 1984); (Fowler 1991); (Swart et al 1993); (Bezuidenhout 1993): (Skadhauge et al., 1984). They differ from poultry in that they do not possess a crop where food may be temporarily stored but the inner lining of their oesophagus is deeply furrowed allowing considerable expansion for the ingestion of bulky feed and the proventriculous is quite distensible and may serve as a food storage organ. In the ostrich the proventriculus can contain 4.5 - 5.5 kg of fresh food mass (Milton et al. 1994).

The total length of the alimentary tract in the emu is extremely short relative to the ostrich and domestic fowl. While the length of the small intestine of the emu and the ostrich in proportion to liveweight is comparable it is much shorter than that of the domestic fowl. The ostrich has a well developed colon and spiralled caecum which is thought to play an important role in the production and absorption of volatile fatty acids (VFA) and other metabolites produced by microbial fermentation of cellulose and hemicellulose (Swart et al 1993a); (Bezuidenhout 1993).

Ostriches can digest plant fibre with an efficiency comparable to large herbivorous mammals, more specifically hemicellulose (66%) and cellulose (38%), and the energy contribution of VFA could be as high as 76% of the metabolizable energy intake of growing chicks (Swart, 1993a). This is consistent with the low rates of passage (mean retention time 40.1 hour) and the food being subject to gastric grinding in the proventriculous and gizzard (Swart et al 1993b).

Herd and Dawson (1984) showed that emus were able to digest 35 - 45 % of the neutral detergent fibre (NDF) of an unspecified diet ie. 50 - 60% of the hemicellulose and up to 20% of the dietary cellulose and lignin. This is in spite of the relatively simple gut and rapid passage time of plant particulate matter (5.5 hours) and of the liquid phase (4.1 hours). The principal site of digestion was the distal small intestine or ileum and while they did not conclusively prove utilisation of the derived energy they concluded that up to 63% of the standard metabolism and 50% of the maintenance requirement for energy could be provided by digestion of the 36% NDF in the highest fibre diet.

Microbial digestion also occurs in the adult domestic fowl and Moran and Evans (1977) recorded 38.6% digestion of the 12% NDF in a low fibre laying diet and 3 1.2% of the 17.8% NDF in a similar but high fibre diet containing oats and wheat shorts. Young growing poultry do not digest fibre well (5 to 6 % of NDF) (Moran 1982).

Energy

This work indicates that the metabolizable energy content of feed ingredients derived for ostriches will be greater than that derived for domestic poultry and possibly greater than that derived for emus. The magnitude of these differences could be expected to vary with age and species and will be dependent on the quantity and type of fibre the feed ingredient contains (Janssen 1985; Longstaff and McNab 1989).

Smith et al., (1995) listed true metabolizable energy contents corrected for nitrogen retention (TME_n) determined by Cilliers 1995; Cilliers et al., 1994). These values should prove invaluable for the establishment of energy requirements and diet formulation for ostrich.

Variation with age

Age related changes in the digestibility of NDF and fat and measures of dietary ME content has been demonstrated in ostriches (Angel 1993). NDF digestibility of the diet containing 7% fat, 16.7% crude fibre and 33.9% NDF was 6.5% at 3 weeks, 51% at 10

Table 1 Comparison of the digestive tract of emus, ostrich and domestic fowl

	Length (mm/kg LW)			Relative Length % of total		
Region	Emu	Ostrich	Fowl	Emu	Ostrich	Fowl
Pro ventriculus	3.6	4.3	7.4	3.7	1.3	8.7
Gizzard	2.9	2.5		3.0	0.8	
Duodenum	13.1	61.9	120	13.4	18.4	15.4
Jejunum	32.1		416	32.8		53.3
Ileum	37.1	54.8	64	37.9	16.3	8.2
Caeca (paired)	1.6	26.2	68	1.6	8.3	8.7
Colon	7.6	184.5	44	7.8	54.9	5.6

weeks and 61.6% at 30 months. Fat digestibility was 44.1% at 3 weeks and 91.1% by 17 weeks of age. The formulated metabolizable energy (ME) of the diet (chicken ME basis) was 1983 kcal/kg. The determined values with ostriches were: 3 weeks, 173 1; 6 weeks, 2337; 10 weeks, 2684; 17 weeks, 2739; and 30 months, 2801 kcal/kg. Angel concluded that ostrich starter diets should not contain high levels of fat and only moderate levels of fibre.

Experience with emus

Similar data for emus is not available and only an indication of the emus' ability to digest fibre and fat can be derived from the diets fed at the Medina Research Centre. In Western Australia the formulation of practical diets with crude fibre levels exceeding 5.5% (NDF 20%) is not economical and we have not fed diets beyond this limit. However, where we have fed diets of lower crude fibre levels (2.8 - 3.0%; NDF

Table 2 TMEn values of feedstuffs as determined with ostriches and roosters on a 90% DM basis (Cilliers, 1995)

Ingredients	Ostriches Mean ± sd	Roosters Mean ± sd
Yellow maize	15.06 + 0.228	14.42 + 0.056
Lucerne hay*	8.91 + 0.119	4.03 + 0.118
Malting barley**	13.93 + 0.251	11.33 + 0.212
Oats	12.27 + 0.291	10.63 + 0.783
Triticale	13.21 + 0.241	11.82 + 0.224
Wheat bran	11.91 + 0.221	8.55 + 0.375
Sunflower oilcake meal	10.79 + 0.278	8.89 + 0.494
Soybean oilcake meal	13.44 + 0.173	9.04 + 0.165
Saltbush hay (Atriplex nummularia)	7.09 + 0.238	4.50 + 0.271
Common reed (Phragmites australis)	8.67 + 0.337	2.79 + 0.147
Sweet white Lupinus albus (Buttercup)	14.61 + 0.340	9.40 + 0.642
Ostrich meat and bone meal	12.81 + 0.203	8.34 + 0.126
Fish meal	15.13 + 0.315	13.95 + 0.190

*Mean of 10 measurements in ostriches
**Mean of 2 measurements in ostriches
The remainder were values determined in one balance study

Table 3 Apparent utilisation of energy by emus fed diets of different fibre content

	Diet 1*			Diet 2**		
Age	gain b/d	MJ/kg gain	NDF %	gain b/d	MJ/kg gain	NDF %
3 - 8 W	104	21.2	20.6	108.8	25.7	12.4
8 - 24 W	129	43.6	20.6	135.3	45.5	13.7
24 - 40 W	93	70.7	20.6	79.2	88.1	14.4
40 - 62 W	91	104.5	20.6	97	110.3	15.2

* Average of 15 replications of 10 birds hatched September 1992 and fed a mash diet formulated to contain 11.0 MJ/kg using ME values for chickens and subjected to 3 different management procedures.

** Average of 20 replications of 10 birds, 10 hatched July 1993, 10 hatched September 1993 and fed a different basal diet, diluted in energy within the range of 13.5 MJ to 10.5 MJ by the removal of fat and dilution with hardwood sawdust for each growth period (no difference found for the parameters averaged).

12 - 15%) the calculated energy (based on chicken ME values) required to achieve a kilogram of gain has been slightly greater (Table 3) and the variation is consistent with the emus digesting the higher levels of NDF contained in the more fibrous diet. There is an obvious need to establish ingredient ME values for emus.

Work completed recently (unpublished) has demonstrated that emus fed *ad libitum* on diets ranging in ME from 10.5 to 13.5 MJ /kg adjusted their intake to a constant level of energy. A fifth diet containing a 25 percent higher level of protein gave no additional growth and a sixth diet, where the birds were allowed to select between an energy and a protein source, suggests they have a preference to select for energy rather than a rational appetite for protein. The range of dietary ME was achieved by removing added fat from the 13.5 MJ diet and diluting it progressively with hardwood sawdust to achieve the other three diets. There was no suggestion of poor fat digestibility, similar to that reported by Angel (1993) for ostriches, when the high energy diet containing 8.8% fat was fed from 3 weeks of age.

Maintenance

An estimate of the daily maintenance energy requirement of emus (Dawson and Herd, 1983) is significantly lower than that determined for ostrich (Swart et al., 1993) and those determined for poultry.

The basal metabolic rate (BMR) of ostrich and emu is 35 - 40% lower than that of other non passerine birds and the BMR of the male emu is 20% lower than that of the female (Maloney and Dawson, 1993).

Table 4 Maintenance requirements

	Emu	Ostrich	Domestic fowl
ME(kj/kg$^{0.75}$/day)	**284**	**440**	**415**

The low maintenance requirement reported for the emu suggests it may prove to be more energy efficient in terms of the amount of dietary energy consumed for each kilogram of liveweight gain. Estimates of dry matter, energy, protein and amino acid requirements for maintenance and growth of ostriches derived by Cilliers, (1995) (Smith et al., 1995) can be used to calculate and compare the amount of feed energy being consumed by ostriches for comparison with data derived from feeding trials with emus. This comparison Figure 6. shows that both appear to be similar in their conversion of feed energy to liveweight over the range measured and at the younger ages both are comparable to that achieved by other intensive livestock industries. At ages greater than 6 months the utilisation of metabolizable energy is poor. Figure 5.

These figures were derived by an extrapolation of requirements determined for ostriches from 2 10 - 230 days of age and assume that the calorific value for younger birds would be the same. This will have resulted in an overestimation of the energy requirements for ostriches under 6 months of age (Smith et al., 1995). The emu data is derived from 4 replications of 10 birds fed a 13.5 MJ/kg (chicken ME values) low fibre diet.

Protein

Du Preez, (199 1) used data from ostriches killed at different ages to calculate protein gain, and from this, requirements for the amino acid lysine and total sulphur amino acids (methionine and cystine). He used the method proposed by Emmans,(1988) which uses body composition analysis to estimate the birds requirements for protein and essential amino acids based on its known growth characteristics. A similar analysis for emus will be completed shortly but it is interesting to compare the amino acid profile of the emu, ostrich and chicken (Table 5.).

While the ostrich has a higher absolute level of lysine in its protein the amino acid pattern of all three species is similar. This has been reported for other species of bird (Fisher and Scougall, 198 1) and it appears that in the absence of more extensive analysis it may be possible to meet the birds amino acid requirements by the feeding of diets of similar amino acid pattern. The amino acid pattern determined for growing chickens corresponds well with the pattern expressed by their body protein, with the exception of methionine, which tends to be inflated, at the expense of cystine (Standing Committee on Agriculture, 1987). It is of interest that the pattern of feed amino acids published by Cilliers is closer to the pattern of chicken rather than that of ostrich.

The amino acid requirements published by Smith et al.,(1995) are similar to those that can be derived from Du Preez, (1991) up to 100 days of age but show higher requirements at older ages.

The lysine requirement of the young growing emu for maximum growth rate and minimum food conversion ratio has been calculated to be 0.9 and 0.825 g lysine/MJ ME respectively (Mannion et al., 1995). On the basis of feeding experience at the Medina Research Centre a level of 0.8 g - 0.9. g lysine/MJ ME had been

Figure 5

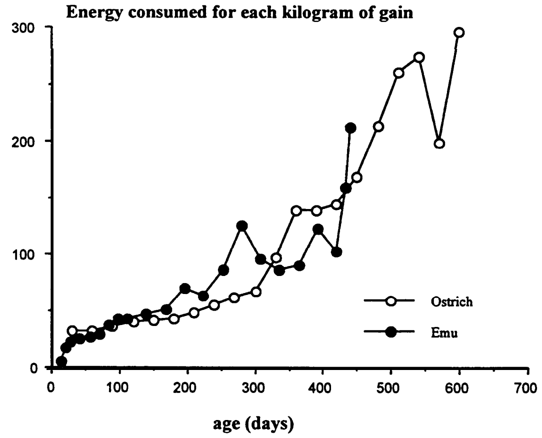


Table 5 Amino acid patterns, relative to lysine, in different species of bird

	Emu	Ostrich	Cilliers, 1995	Chicken
Cystine	16		25	39
Aspartic Acid	136			
Methionine	31	33	31	30
Threonine	66	53	61	73
Serine	73	43		
Glutamic Acid	219			
Proline	120			
Glycine	166			175
Alanine	117	41		
Valine	67	69	79	111
Iso Leucine	56	56	84	82
Leucine	117	112	135	133
Tyrosine	48	38	44	51
Phenylalanine	73	62	80	70
Lysine	100 (5.84)*	100 (6.68)	100 (6.8)	100 (5.55)
Histidine	44	44	38	37
Arginine	115	89	95	96
Tryptophan		12		16

* g/16gN
Cilliers, (1995): average of estimate of feed requirement for 180 and 420 days of age.
Emu data: Average of six 20 week old emus (featherless body)
Ostrich data: Du Preez, 1991
Chicken data: Fisher and Scougall, 1981

Table 6 Suggested nutritional restraints for the formulation of emu rations

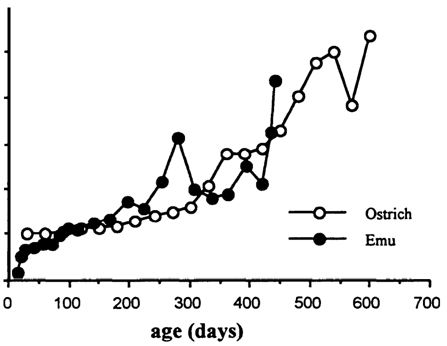
0-8 weeks	8-20 weeks	20-40 week	40-70 week	Breeder	
Protein % >	16.5	16.5	15.0	13.0	15.0
g Lysine/MJ energy	0.80	0.65	0.60	0.48	
AA Ratio to Lysine					
Lysine 1.00	1.00	1.00	1.00	0.70%	
Methionine >	0.40	0.50	0.50	0.50	0.32%
TSAA >0.75	0.66	0.66	0.66	0.59%	
Arginine >	0.90	1.04	1.04	1.04	1.21%
Isoleucine >	0.50	0.57	0.57	0.57	0.51%
Isoleucine <	0.76	0.76	0.76	0.76	
Leucine >	1.03	1.36	1.36	1.36	0.98%
Leucine<	1.72	1.72	1.72	1.72	
Phenylalanine>	0.70	0.70	0.70	0.70	0.59%
Threonine>	0.60	0.60	0.60	0.60	0.51%
Tryptophan .	0.19	0.19	0.19	0.19	0.16%
Valine >	0.68	0.81	0.81	0.81	0.67%
Valine <	0.94	0.94	0.94	0.94	
Energy MJ >	11.0	10.5	11.0	11.0	10.5
Fat % > 4.0	4.0	4.0	4.0	4.5	
Linoleic Acid % >	1.0	1.0	1.0	1.0	0.9
Fibre % >	4.0	4.0	4.0	4.0	4.5
Calcium >%	1.2	1.2	1.2	1.2	3.0
Available Phosp >	0.65	0.60	0.40	0.40	0.51
Available Phosp <	0.80	0.80	0.80	0.80	
Sodium >	0.16	0.16	0.16	0.16	0.15

recommended to the industry (Table 6). The ratio of other amino acids to lysine have been those recommended for growing chickens. Listed below are my current recommendation for the feeding of emus. Emus have failed to show a response to protein levels higher than those presented in this table (unpublished) and I feel that for ages beyond 40 weeks they are still in excess of the emus' true requirement.

The estimates of nutritional requirements and growth for the ostrich (Smith et al, 1995), can be compared with the known performance of emus fed to the specification above to compare the amount of protein emus and ostriches consume for unit increase in liveweight (Figure 6.).

Figure 6

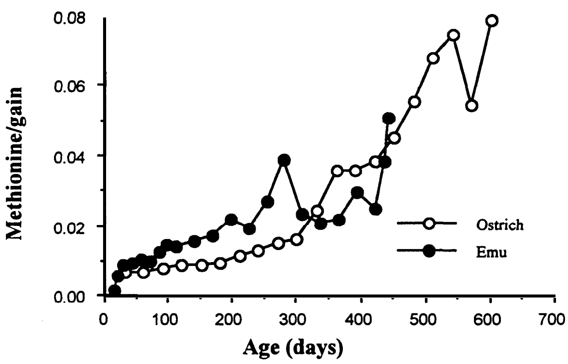
Dietary protein required for each unit increase in live weight



While the two graphs are similar young emus do appear to be utilising the dietary protein better than ostriches. Similar graphs can be drawn for the amino acids methionine and TSAA. These show that relative to ostriches, we are recommending levels of methionine which show poor utilisation and suggests that the high levels of methionine used, may not be appropriate (Figure 7).

Figure 7.

Dietary intake of methionine per unit live weight gain



Practical diet specifications have been given for ostriches in various stages of production (Smith et al, 1995) Table 8.

Breeders

Amino acid and energy requirements for maintenance and egg production for ostriches were calculated by Du Preez, (1991). No similar exercise has been undertaken for emus and there has been no published feeding trials. Angel, (1993) reported on nutrient profiles of emu and ostrich eggs as indicators of nutritional status of the hen and chick. She observed a selenium toxicity problem (6.7 ppm DM) in eggs laid by hens fed selenium supplemented diets and low manganese levels in both emu and ostrich eggs despite a diet value of 195 ppm manganese. A study of baseline values for skeletal (leg bone) growth, calcification, and soft tissue (liver) mineral accretion (Scheidler et al., 1994) also suggested that low manganese levels may be contributing to leg trauma problems and work on the availability of manganese from supple-

Table 8 Dietary Specifications for Ostriches

	PRE STARTER 0.8 - 11 kg LW 0 - 2 months 18 cm chest	STARTER 11 - 28 kg LW 56 cm chest 4 - 6 months	GROWER 2 - 4 months 28 - 52 kg LW 79 cm chest
TME$_n$ ***MJ./kg DM***	***13.2***	***12.8***	***12.2***
PROTEIN g/kg DM	255.0	215.0	171.0
LYSINE g/kg DM	12.5	10.7	9.0
METHIONINE g/kg DM	3.6	3.2	2.7
TSAA g/kg DM	6.9	6.0	5.0
ARGININE g/kg DM	11.5	10.0	8.5
THREONINE g/kg DM	6.6	6.5	5.5
ISO LEUCINE g/kg DM	10.3	8.9	7.6
LEUCINE g/kg DM	17.0	14.8	12.2
CALCIUM %	1.2 - 1.5	1.2 - 1.5	1.2 - 1.5
AVAIL. PHOSPH. %	0.4 - 0.45	0.4 - 0.45	0.4 - 0.45
SODIUM %	0.20 - 0.25	0.20 - 0.25	0.20 - 0.25

ments traditionally used in poultry premixes warrants examination.

Excessive fatness is considered to be a problem in the ostrich industry causing a high incidence of infertile eggs (Smith et al., (1995). The high calcium level in layer diets is also reported to reduce the availability of zinc causing infertility in the male.

Fatness does not appear to be a problem with breeding emus and birds will eat less of a high energy diet and once fat reserves are fully restored, following the winter in - appetence period, appear to eat to maintenance level before commencing to loose weight in the following autumn.

The information presented is based on the few scientific papers published and the information recorded at the Medina Research Centre. Much is based on data derived from single studies and some of the work requires verification. It will be some time before sufficient information is available to enable the calculation of the most economically appropriate diet for each growth phase. I feel the industries have more to gain from an understanding of the utilisation of dietary energy by these birds and work in this area should be encouraged.

Unfortunately it will be some time before the priorities of either industries are directed toward nutrition research. The ostrich industry is faced with a very real production problem in egg hatchability and chick survival and the emu industry is focused on market and product development.

References

Angel, Roselina. 1993. Age changes in the digestibility of nutrients in ostriches and Nutrient profiles of ostrich and emu eggs as indicators of nutritional status of the hen and chick. Proceedings Association of Avian Veterinarians 1993

Angel, Roselina. 1994. Diet effect on egg nutrients in a high producing ostrich. Ostrich Odyssey 1994.

Bezuidenhout, A. J. 1993 The spiral fold of the caecum in the ostrich (Struthio camelus). 1993 Journal of Anatomy 183. pp. 587-592.

Cilliers, S. J. Hayes, J.P. Maritz, J.S. Chwalibog, A. du Preez, J. J. 1994. True and apparent metabolizable energy values of lucerne and yellow maize in adult roosters and mature ostriches. Animal Production 59: 309-3 13.

Davies, S.J.J.F. 1978. The food of emus. Australian journal of Ecology 3,4 1 1-422.

Dawson, T.J. and Herd, R.M. 1983. Digestion in the emu: Low energy and nitrogen requirements of this large bird. Comparative Biochemistry and Physiology 75A. No 1. pp 41-45.

du Preez, J.J. 199 1. Ostrich nutrition and management. In: Recent Advances in Animal Nutrition in Australia. D.J. Farrell (Ed.) University of New England, Armidale, Australia, 278.

du Preez, J. J. Jarvis, M.J.F Capatos, D. and de Kock, J. 1992.A note on growth curves for the ostrich (Struthio camelus) Animal Production 54: 150-1 52.

Fisher, C. and Scougall, R.K. 1982. A note on the amino acid composition of the turkey. British Poultry Science **23: 233-237.**

Table 9

	FINISHER 52 - 91 kg LW 6 - 10 months 95 cm chest	POST FINISH 91-107 kg LW 10 - 20 months 112 cm chest	MAINTENANCE MATURE LW	LAYE MATI SEASO
TME_n MJ./kg DM	10.9	8.0	6.5	9.2
PROTEIN g/kg DM	135.0	85.0	80.0	140.0
LYSINE g/kg DM	8.4	6.3	2.7	6.8
METHIONINE g/kg DM	2.6	2.0	1.1	3.2
TSAA g/kg DM	4.6	3.5	2.1	5.3
ARGININE g/kg DM	8.1	6.1	3.2	7.0
THREONINE g/kg DM	5.1	3.8	1.7	5.3
ISO LEUCINE g/kg DM	7.2	5.4	1.6	5.1
LEUCINE g/kg DM	11.2	8.4	3.3	8.8
CALCIUM %	0.9 - 1.0	0.9 - 1.0	0.9 - 1.0	2.0 - 2.
AVAIL. PHOSPH. %	0.32 - 0.36	0.32 - 0.36	0.32 - 0.36	0.35 - 0.
SODIUM %	0.15 - 0.30	0.15 - 0.30	0.15 - 0.30	0.15 - 0.

Fowler, M.E. 1991, Comparative clinical anatomy of Ratites. Journal of Zoo and Wildlife Medicine 22(2): 204-227.

Frapple, P and O'Malley, P. 1994. Report on Travel to America to Attend the Emu Extravaganza, Reno. prepared for the Rural Industries Research and Development Corporation. Australia.

Herd, R.M. 1983. Anatomy and histology of the gut of the emu dromaius novaehollandiae. The Emu Vol. 85 part 1.

Herd, R.M. and Dawson, T.J. 1984. Fibre digestion in the emu, Dromaius Novaehollandiae, a large bird with a simple gut and high rates of passage. Physiological Zoology 57(1): 70-84

Janssen, W.M. and Carre', B. 1985. Influence of fibre on digestibility of poultry feeds. Recent advances in animal nutrition - 1985. pp 71-86. London United Kingdom; Butterworths.

Longstaff, M. and McNab, J.M. 1989. Digestion of fibre polysaccharides of pea (Pisum sativum) hulls, carrot and cabbage by adult cockerels. British Journal of Nutrition 62: 563-577.

Maloney, S.K. and Dawson, T. J. 1993. Sexual Dimorphism in the basal metabolism and body temperature of a large bird, the emu.

Mannion, P.F. and Kent, P.B. Barram, K.M. Trappett, P.C. and Blight, G.W. 1995, Australian Emu March/April: pp 12-18.

McKinna et al., Report prepared for the Austrlain Ostrich Association.

Milton, S. J. Dean, W.J. W. and Siegfried, W.R. 1994. Food selection by ostrich in South Africa. Journal of Wildlife Management. 58(2): 234-247.

Moran, E.T. and Evans, E. 1977. Performance of and nutrient utilisation of laying hens fed practical rations having extremes in fibre content. Canadian Journal of Animal Science. 57: 433-438.

Scheideler, S.E. Wallner-Pendleton, Schneider N. E.A. Carlson, M. 1994. Determination of baseline values for skeletal (leg bone) growth, calcification, and soft tissue (liver) mineral accretion. Report to the American Ostrich Association.

Skadhauge, E. Warui, C.N. Kamau, J.M.Z. and Maloiy, G.M.O. 1984. Function of the lower intestine and osmoregulation in the ostrich: Preliminary anatomical and physiological observations. Quarterly Journal of Experimental Physiology 69,809-g 18.

Smith, W.A. Cilliers, S.C. Mellett, F.D. and Van Schalkwyk, S.J. 1995 Ostrich Production - A South African Perspective. Biotechnology in the Feed Industry. Proceedings of Alltech's Eleventh Annual Symposium. 1995. T.P. Lyons and K.A. Jacques{ Eds. } Nottingham University Press Nottingham.

Standing Committe on Agriculture Poultry Subcommittee. 1987. Feeding Standards for Australian Livestock - Poultry. 1987

Swart, D. Machie, R.I. and Hayes, J.P. 1993(a) Fermative digestion in the ostrich (Struthio camelus var. domesticus), a large avian species that utilises cellulose. South African Journal of Animal Science 23(5/6) 127-135.

Swart, D. Machie, R.I. and Hayes, J.P. 1993(c) Growth, feed intake and body composition of ostriches (Struthio camelus) between 10 and 30 kg live mass . South African Journal of Animal Science 23(5/6)119-125.