Feeding Guidelines for Ratites in Zoos

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Description of the animal

Ratites (Order Struthioniformes) are flightless birds, with a raft-like breastbone devoid of a keel, and can be classified into five different families (Table 1).

Table 1 Different families of living ratites (Drenowatz et al., 1995)

Family	Species	Common name	Adult weight (kg)
Struthionidae	*Struthio camelus*	Ostrich	90-130
Rheidae	*Rhea americana*	Greater rhea	25
	Pterocnemia pennata	Lesser rhea	25
Casuariidae	*Casuarius casuarius*	Double-wattled cassowary	55
	Casuarius unappendiculatus	Single-wattled cassowary	
	Casuarius *bennetti*	Dwarf cassowary	
Dromiceiidae	*Dromaius novaehollandiae*	Emu	41
Apterygidae	*Apteryx australis*	Brown kiwi	2
	Apteryx hoastii	Great spotted kiwi	
	Apteryx awenii	Little spotted kiwi	

Despite their similarities to other birds, ratites have evolved unique characteristics in order to survive in their natural habitat. Of interest from a nutritional standpoint are the modifications in the gastrointestinal tract and the functional characteristics these changes allow (Angel, 1996). Ratites do not have teeth or a crop, which is a feed storage organ in other avian species. While fibre fermentation appears to take place in the large intestine (colon) of the ostrich, the distal ileum serves as a fermentation organ in the emu. The most distinctive characteristic of the gastrointestinal tract of the rhea is the relative large cecum (Table 2).

Table 2 Comparison of the digestive tract of ostriches, emus and rheas (Cho et al., 1984; Fowler, 1991; Angel, 1996)

Region	Length (cm)			Relative length (% of total)		
	Ostrich	Emu	Rhea	Ostrich	Emu	Rhea
Small intestine	512	351	140	36	90	61
Cecum	94	7	48	6	2	21
Colon	800	28	40	57	7	17

Emus should be able to derive marginally more energy from plant fibre than the domestic fowl, but is unlikely to approach the efficiency of digestion demonstrated by the ostrich (O'Malley, 1995).

Ostriches (Sauer and Sauer, 1966) and rheas (Cajal, 1988) are adaptable grazers/browers, while the emu is an opportunistic feeder (Davies, 1978). The ostrich can also be considered as a "monogastric" herbivore, which means that it is a simple stomached animal which has developed the ability to utilize forage (Smith and Sales, 1995). The ability of the ostrich to digest fibre (NDF) increased linearly up to the age of 10 weeks. After 10 weeks of age it continued to increase, but at a slower rate, reaching a plateau at 17 weeks (Angel, 1993).

Feeding ecology

The natural environment of ostriches varies from arid or semi-desert terrain to grasslands. Ostriches are natural plant-eaters living on succulents, seeds, berries, grass and leaves of trees and shrubs. Diet calcium is supplemented by the intake of bones, eggshells and sea shells. The weighted average chemical composition of the plants selected by free-ranging Namib desert ostriches was: protein 11.2 %, lipids 4.2 %, fibre 35.2 %, ME 8.87 MJ/kg (Williams et al, 1993). According to Milton et al. (1993) ostriches will select plants with 24 % protein and 70 % water when given a wide choice of foods. They rarely eat dead grass. An ostrich need 5-6 kg fresh mass daily when feeding on natural forage containing 70 % water (Milton et al., 1994).

Emus in semi-arid and arid areas of Australia have a preference for high quality items such as green plant material, seed heads, ripening fruit, berries and insects. The selection does not include dried herbage or grass nor the mature leaves of shrubs (Davies, 1978). Ninety percent of the diet of wild greater rheas consist of green material, followed by seeds (9 %), fruits, and fragments of invertebrates and vertebrates (Martella et al., 1996).

Kiwi are omnivorous, but their diet consists mainly of invertebrates such as beetle larvae, cicada nymphs, worms, beetles, crickets, fly larvae, weta, spiders, caterpillars, slaters, slugs and snails. They also eat berries, seeds, and some leaves. The cassowary is a frugivorous bird, but will also eats fungi, insects, frogs, snakes and other small animals.

Ratite diets

Since the domestication of the ostrich as a farm animal around 1865 in South Africa (Drenowatz et al., 1995) many different diets have been utilised in ostrich production, varying from single ingredients such as lucern to compound diets with several ingredients including

vitamin/mineral mixtures. The first book on ostrich feeds and feeding was already published in 1913 by Dowsley and Gardner. Since what can be termed the "third ostrich boom" in 1990 and the spread of ostrich farming to countries outside South Africa, the ostrich industry relies entirely on the use of compound commercial manufactured diets, mostly in a pelleted form. The same is a true for the emu since emu farming was recognised as being technical feasible in Australia and the expanding of flocks to the USA, Europe and China (O'Malley, 1995). On the few commercial pilot operations for the domestication of the rhea as farm animal in South America a variety of compound pelleted diets, consisting mainly of lucern and maize meal, are fed (Sales et al., 1997).

Although commercial ostrich and emu diets were initial based on specifications determined for poultry, studies by Cilliers (1995) and O'Malley (1995) have revealed significant information on the nutrient requirements of these two species (Tables 3 and 4).

However, a commercial operation differs from animals kept in a zoo. The numbers of any age class that are owned by a zoo are so few that it is difficult to keep age classes separate, to stock several diets (starter, grower, maintenance), and to keep the diets fresh. It may thus be more practical to use a single diet that represents a formulation compromise but one that meets needs at any stage of the life cycle (Ullrey and Allen, 1996). Specifications for such a diet, that can be pelleted and fed *ad libitum* with water on pasture or in a dry lot are presented in Table 5, and compared to diet recommendations for ostriches in intensive farming conditions. Differences in recommended specifications for minerals and vitamins are evident, however, no research have been conducted on this topic in ratites. The ability of the zoo recommended diet (Ullrey and Allen, 1996) and the "mean" recommended diet for intensive production conditions (Cilliers and Van Schalkwyk, 1994) to fulfil in the protein (at 65 % digestibility), lysine (at 83 % digestibility) and methionine (at 82 % digestibility) requirements of emus and ostriches are presented in Figs. 1, 2 and 3. The above digestibility values for protein, lysine and methionine were from Cilliers et al. (1997). Although the "mean" production diet will undersupply amino acids for ostriches till about 300 days, this diet can be recommended, seen that the ostriches in zoos are not kept for maximum growth as in commercial production. In a zoo where eggs are normally not removed to force increase egg production, the concentration of calcium in this diet should be adequate for production of a normal clutch. A total calcium concentration of 2.0 to 2.5 % is recommended for layers in intensive production systems (Cilliers and Van Schalkwyk, 1994).

Table 3 Estimated dry matter intake (DMI)*, energy, protein and amino acid requirements for maintenance and growth of ostriches (Cilliers, 1995)

AGE (Days)	LW (kg)	ADG (g/b/d)	DMI (g/b/d)	TME_n (MJ/kg DMI)	Prot (g/kg DMI)	Amino acids (g/kg DMI)										
						Lys	Met	Cys	Arg	Thr	Val	Isoleu	Leu	His	Phe	Tyr
30	4.0	105	220	15.2**	239	10.6	3.1	2.8	9.8	6.5	7.9	8.7	14.5	3.6	8.5	4.4
60	11.0	233	440	17.5**	272	12.5	3.6	3.3	11.5	7.6	9.3	10.3	17.0	4.3	10.0	5.1
90	19.5	283	680	15.3**	224	10.8	3.2	2.8	10.1	6.6	8.2	9.0	14.7	3.8	8.7	4.5
120	28.5	300	820	14.9**	207	10.6	3.2	2.7	9.9	6.4	8.1	8.8	14.3	3.8	8.5	4.5
150	39.5	367	1220	12.5**	174	9.1	2.7	2.3	8.5	5.5	7.0	7.6	12.3	3.3	7.3	3.9
180	52.1	420	1490	12.2**	168	9.0	2.7	2.3	8.5	5.5	6.9	7.6	12.2	3.3	7.2	3.9
210	63.4	375	1630	11.3	148	8.5	2.6	2.1	8.0	5.1	6.6	7.2	11.4	3.1	6.8	3.7
240	73.3	330	1710	10.8	135	8.2	2.5	2.0	7.8	5.0	6.4	7.0	11.0	3.1	6.6	3.6
270	82.4	305	1760	10.7	130	8.3	2.6	2.0	7.9	5.0	6.5	7.1	11.1	3.1	6.6	3.7
300	91.0	287	1800	10.8	128	8.4	2.6	2.0	8.1	5.1	6.7	7.2	11.2	3.2	6.7	3.8
330	96.3	177	2160	8.0	85	6.3	2.0	1.5	6.1	3.8	5.1	5.4	8.4	2.4	5.0	2.9
360	99.9	120	2210	7.4	74	5.9	1.9	1.3	5.7	3.5	4.8	5.1	7.8	2.3	4.7	2.7
390	103.5	120	2250	7.4	74	5.9	1.9	1.4	5.8	3.6	4.8	5.2	7.9	3.3	4.7	2.7
420	107.0	117	2250	7.5	75	6.1	2.0	1.4	5.9	3.7	4.9	5.3	8.1	2.4	4.8	2.8
450	110.0	100	2250	7.5	73	6.1	2.0	1.4	5.9	3.7	5.0	5.3	8.0	2.4	4.8	2.8
480	112.3	77	2250	7.3	69	6.0	1.9	1.3	5.9	3.6	4.9	5.2	7.9	2.4	4.8	2.8
510	114.2	63	2250	7.3	67	6.0	1.9	1.3	5.9	3.6	4.9	5.2	7.9	2.4	4.7	2.8
540	116.0	60	2250	7.3	67	6.0	2.0	1.3	5.9	3.6	5.0	5.3	8.0	2.4	4.8	2.8
570	118.6	87	2250	7.7	74	6.4	2.1	1.4	6.2	3.8	5.2	5.6	8.4	2.5	5.1	3.0
600	120.3	57	2250	7.5	68	6.2	2.0	1.4	6.1	3.7	5.1	5.4	8.2	2.5	4.9	2.9

Total energy retention measured in empty body weight (EBW). Maintenance was calculated according to 0.678 g/kg EBW. Energy retention as lipid and protein retention was separately calculated. Amino acid retention in feathers and body was calculated separately and requirements for maintenance were calculated using mature defeathered amino acid weight and mean defeathered tyrosine weight.

* Based on a diet with a TME_n (ostrich) content of 11.25 MJ/kg

** In calculating TME_n requirements from results obtained for 7 months old birds similar energy contents were assumed for younger birds. This assuption is incorrect, resulting in an overestimation of dietary energy requirements.

Table 4 Estimated dry matter intake (DMI)*, protein and amino acid requirements for maintenance and growth of emus (O'Malley, 1996)

AGE (Weeks)	LW (kg)	ADG (g/b/d)	DMI (g/b/d)	Prot (g/kg DMI)	Amino acids (g/kg DMI)					
					Lys	Met	Met+Cys	Thr	Isoleu	Leu
0-2	0.5	14	35	119	6.5	1.8	5.9	5.8	5.0	13.1
2-3	0.8	59	88	170	9.8	2.8	6.7	7.9	6.7	17.4
3-4	1.3	80	140	151	8.7	2.5	5.7	6.9	5.9	15.2
4-6	2.3	106	220	137	7.9	2.2	4.8	6.2	5.4	13.7
6-8	3.9	124	259	146	7.7	2.3	5.0	6.7	5.8	14.7
8-10	5.9	153	368	133	7.1	1.8	4.1	6.1	5.3	13.3
10-12	7.8	121	374	116	6.4	1.8	4.1	5.4	4.7	11.8
12-16	10.7	145	561	94	5.3	1.5	3.4	4.4	3.8	9.7
16-20	14.6	134	603	90	5.0	1.5	3.6	4.2	3.7	9.4
20-24	18.2	125	630	89	5.0	1.6	3.8	4.2	3.7	9.4
24-28	23.8	92	597	91	5.2	1.6	4.1	4.4	3.8	9.8
28-32	23.8	95	545	114	6.7	2.1	5.1	5.5	4.8	12.3
32-36	26.1	71	544	116	7.0	2.1	5.3	5.7	4.9	12.6
36-40	28.0	58	614	110	6.9	2.1	5.1	5.4	4.7	12.0
40-44	30.0	80	604	134	8.7	2.5	6.0	6.6	5.6	14.6
44-48	32.5	110	820	113	7.5	2.2	5.0	5.5	4.7	12.3
48-52	35.7	117	851	112	7.3	2.2	5.0	5.4	4.7	12.1
52-56	38.8	104	829	114	7.6	2.2	5.1	5.6	4.8	12.4
56-60	41.5	87	1051	88	5.8	1.7	3.9	4.3	3.7	9.6
60-62	43.1	72	1026	88	5.8	1.6	3.9	4.3	3.8	9.6
62-63	44.0	98	1175	84	5.6	1.6	3.6	4.1	3.6	9.2

* Based on a diet with an gross energy content of 11.5 MJ

Table 5 Recommended nutrient specifications for a diet suitable for ratites (DM basis)

Nutrient	Ullrey and Ellen (1996)[a]	Cilliers and Van Schalkwyk (1994)[b]	Janssens et al. (1997)[c]	
			Minimum	Maksimum
Crude protein (g/kg)	244	154	145	207
Lysine (g/kg)	13	9	7	9
Arginine (g/kg)	14	8	8	10
Methionine (g/kg)	4	3	3	4
Methionine + cysteine (g/kg)	8	-	5	7
Tryptophan (g/kg)	3	-	2	-
Threonine (g/kg)	-	-	5	7
Crude fibre (g/kg)	111	-	95	182
Linoleic acid (g/kg)	11	-	-	-
Calcium (g/kg)	18	12.5-15	10	17
Phosphorus (g/kg)	11	-	6	11
Phosphorus, available (g/kg)	9	3.5-3.9	3	5
Sodium (g/kg)	2	1.6-2.8	2	3
Potassium (g/kg)	12	-	11	-
Magnesium (g/kg)	2	0.05	0.4	1.5
Iron (mg/kg)	167	30	31	142
Copper (mg/kg)	22	15	5	75
Zinc (mg/kg)	133	73	80	123
Manganese (mg/kg)	78	107	102	131
Iodine (mg/kg)	1	0.8	0.6	0.9
Selenium (mg/kg)	0.3	0.25	0.25	0.3
Thiamin (mg/kg)	8	-	2	4
Riboflavin (mg/kg)	10	-	7	8.5
Niacin (mg/kg)	78	52	48	65
Pantothenic acid (mg/kg)	33	13	15	23
Vitamin B_6 (mg/kg)	5.6	3.7	3	5
Biotin (mg/kg)	0.3	0.1	0.2	0.8
Folacin (mg/kg)	1	-	1	2.5
Vitamin B_{12} (mg/kg)	0.03	0.07	0.02	0.03
Choline (mg/kg)	1778	383	775	1300
Vitamin A (IU/kg)	8889	12000	9167	116000
Vitamin D_3 (IU/kg)	1778	2500	2767	3300
Vitamin E (IU/kg)	278	27	-	-
Vitamin K (menadione equivalent) (mg/kg)	4.4	2.7	-	-

[a] recommended for ostriches, emus and rheas
[b] means of recommended diets for ostriches in production over seven different diets from prestarter till layer
[c] means of recommended diets for ostriches in production over seven different diets from prestarter till layer summarised from different sources; not indicated if on DM or as-fed basis

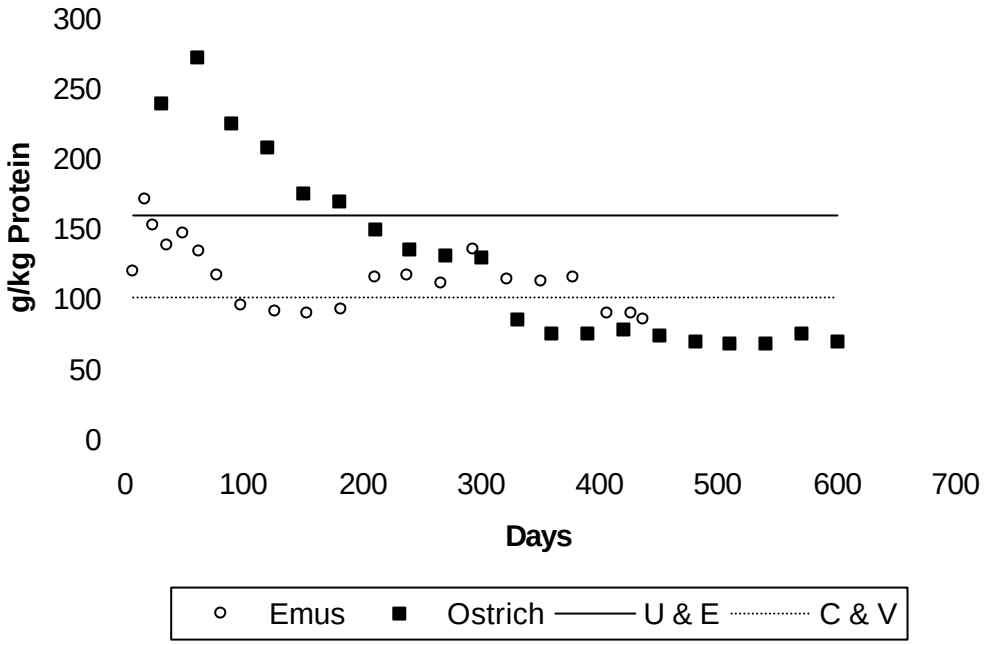

Fig. 1 Ability of recommended zoo diet (U & E: Ullrey and Ellen, 1996) and recommended "mean" production diet (C & V: Cilliers and Van Schalkwyk, 1994) at 65 % protein digestibility to fulfil in the protein requirements of emus and ostriches.

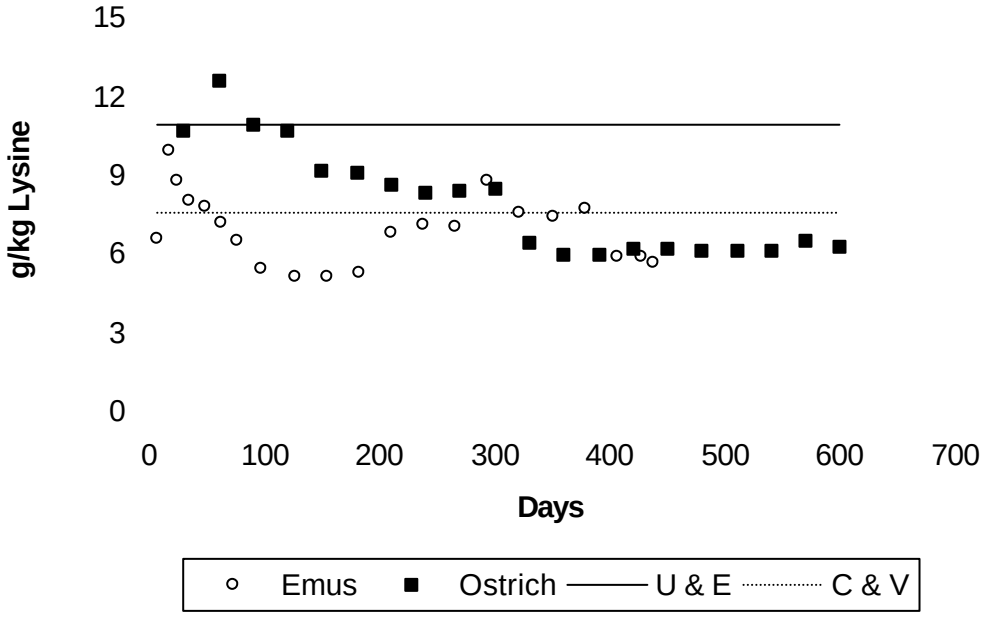

Fig. 2 Ability of recommended zoo diet (U & E: Ullrey and Ellen, 1996) and recommended "mean" production diet (C & V: Cilliers and Van Schalkwyk, 1994) at 83 % lysine digestibility to fulfil in the lysine requirements of emus and ostriches.

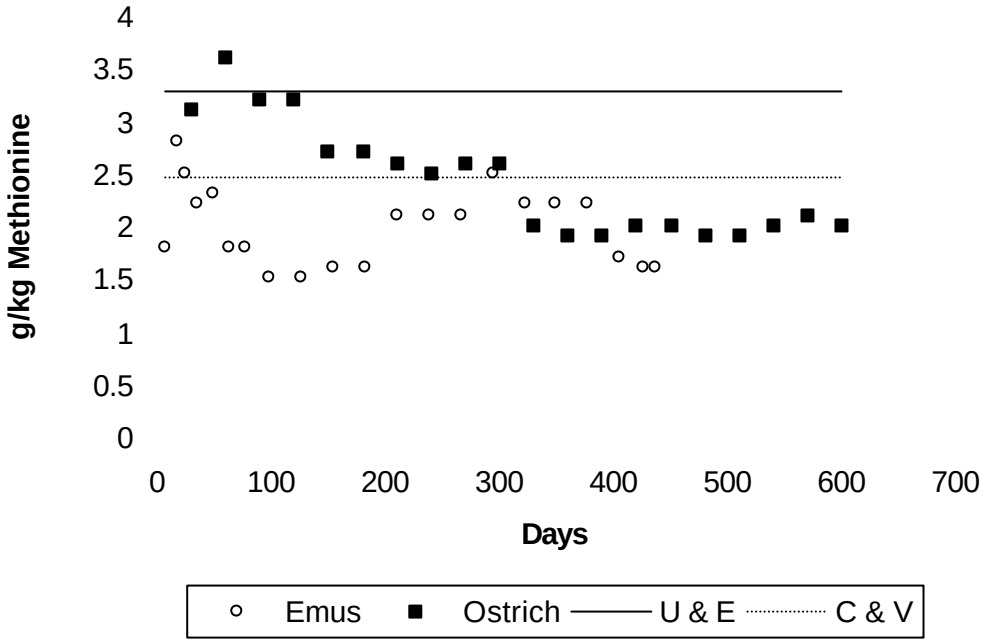

Fig. 3 Ability of recommended zoo diet (U & E: Ullrey and Ellen, 1996) and recommended "mean" production diet (C & V: Cilliers and Van Schalkwyk, 1994) at 82 % methionine digestibility to fulfil in the methionine requirements of emus and ostriches.

The calcium concentration should also be adequate to prevent leg problems such as rickets in growing birds up to four months of age. Under intensive farming conditions leg problems seldom occur in young birds fed a diet with calcium levels around 1.5 to 1.6 % (Verwoerd et al., 1999).

Although ostriches survived for long periods without water in the wild, they will drink large quantities when water is available. Water is nevertheless of great importance in maintaining food intake (Van Niekerk, 1995). According to Dawson et al. (1984) water requirements of wild adult emus do not appear high, but intake may be limited by the size of the gut, resulting in a relatively high frequency of drinking.

Hand rearing

Rearing of young ostriches is a well established practice (Sales and Smith, 1995; Deeming et al., 1996; Verwoerd et al., 1999).

Hatched ostrich chicks can be reared (Sales and Smith, 1995):

- Extensively with foster parents (25 to 30 chicks per adult pair).
- Semi extensively with foster parents (approximately 100 chicks per adult pair) with housing during night time only.
- Semi-intensively by moving outdoors on pastures during daytime from the age of three days.
- Intensively (three weeks to one month in a rearing house).

Ostrich feed and water should be available from day one. A chopped fresh lucern or grass topping of diets will stimulate chicks to start eating. It was also found in rhea chicks (Kruczek, 1968; Bruning, 1973) that the first few chicks required frequent stimulation, for example by poking with a finger or pencil at the food, to induce proper feeding.

Many ostrich producers supplement the starter diet or the water of the newly hatched ostrich with a booster pack containing the following ingredients (Smith and Sales, 1995):

- Electrolytes that will ensure that the correct ratio of Na:K will be consumed and that the absorption of moisture will be normal during these early stages of life. Electrolyte balance and normal moisture levels are essential for optimum dry matter intake and to prevent dehydration of the young bird.
- Acidification substances that will lower the pH of the digestive tract. Young birds secrete limited amounts of gastric acid which restrains their ability to digest complex protein molecules. Supplementing the natural gastric acids of the young bird will enhance its adaptation to high protein starter diets.
- Amylase, protease and cellulase enzymes are supplemented to ensure more efficient digestion of starch, protein and fibre in the young bird and to ensure still better adaptation on starter diets.
- Vitamin A,D,E and B-complex are supplemented to ensure immunity against infections and other diseases.

Supplementation of these biological aids through the drinking water will ensure that young birds with poor feed intake are stimulated to eat and will also have optimal immunity levels. It is well known that the ostrich has poor resistance against infectious and other diseases. The

supplementation of any product (for example yoghurt) that might stimulate immunity is recommended.

Growth of domesticated ostriches in Oudtshoorn, South Africa (Cilliers et al., 1995), were described by means by the Gompertz equation from the form:

$C = C_m \times \exp(-\exp(-B \times (t-t^*)))$

where C_m is the final mature weight,

B is the growth constant

t^* is the time from hatching

Parameters as presented in Table 6 were derived.

Table 6 Growth parameters for male (n = 26) and female (n =17) ostriches

Sex	C_m (kg)	B	t^*(days)
Male	119.2	0.0091	180
Female	122.3	0.0085	199

A similar approach by O'Malley (1995) on a domesticated flock of emus in Australia was unfortunately only presented in graph form. Variation in growth rate of young growing domesticated emus appears to be associated with seasonal effects on voluntary intake. Mature emus also exhibit seasonal variation in feed intake with the appetite of breeding birds rising sharply as egg production ceases in late winter before declining sharply as the new breeding season commences in the following autumn.

Growth of Lesser rhea (Bruning, 1973; n = 18) and Double-wattled cassowary chicks (Schmitt, 1983; n = 33) in zoos are presented in Fig. 4.

Recommendations

A single pelleted diet over all age classes is recommended for ratites. This diet is based on nutrient values recommended for intensive ostrich production, thus it is the mean values of several diets recommended during different stages of the life cycle. The result is that the diet will undersupply amino acid requirements up to 300 days, and oversupply amino acids thereafter, for ostriches. For emus, however, an oversupply will be found during most of the life cycle. No information exists about nutrient requirements of rheas, cassowaries or kiwis.

The suggestion is to evaluate the suggested diet, with a fibre component of around 15 % included into it, for all different species of ratites. Especially the acceptability of this diet by cassowaries and kiwis, and the digestibility of the diet for different species, warrant investigation.

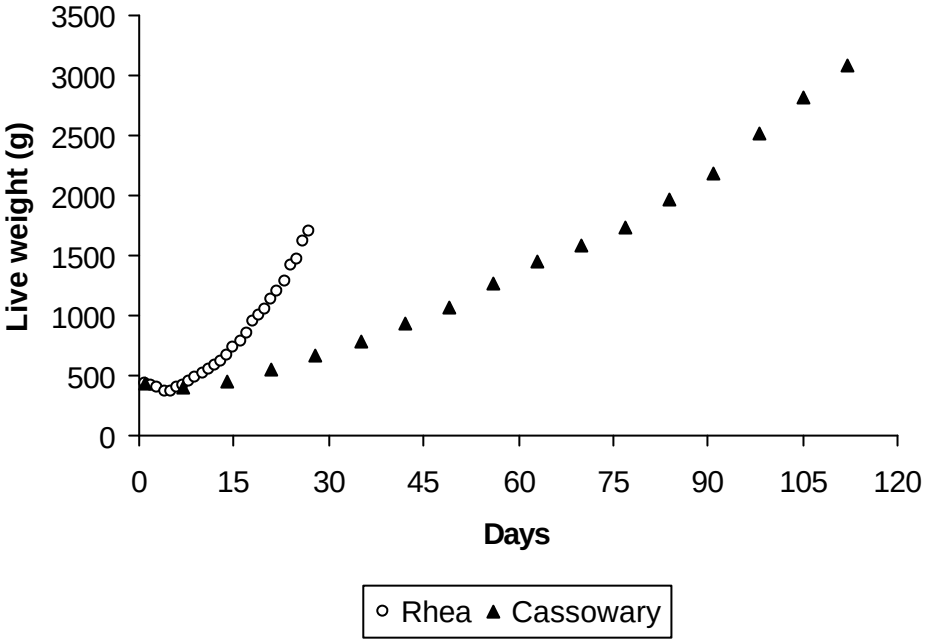

Fig. 3 Growth of Lesser rhea (Bruning, 1973) and Double-wattled cassowary (Schmitt, 1983) chicks in captivity.

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Appendix A Reference values for the biochemical values in blood from ostriches from a variety of ages and both genders (Levy et al., 1989) and adult emus(Fudge, 1995)

Parameter	Ostriches	Emus
Protein (g/l)	0.37	0.34-0.44
Clucose (mg/l)	24.8	11.4-20.3
Triglycerides (mg/l)	9.0	-
Cholesterol (mg/l)	9.7	4.2-16.6
Uric acid (mg/l)	0.82	0.07-0.87
Bilirubin (mg/l)	5.9	-
Creatinine (mg/l)	0.03	0.01-0.04
Alkaline phosphatase (IU/l)	575	-
Alanine aminotransferase (IU/l)	2.0	-
Creatinine phosphokinase (IU/l)	688	70-818
Lactate dehydrogenase (IU/l)	1565	318-1243
Aspartate aminotransferase (IU/l)	131	80-380
γ-Glutamyltranspeptidase (IU/l)	1.5	-
Sodium (mmol/l)	147	-
Potassium (mmol/l)	3.0	-
Chlorine (mmol/l)	100	-
Magnesium (mmol/l)	1.1	-
Phosphorus (mg/l)	0.50	0.38-0.72
Calcium (mg/l)	0.92	0.88-1.25

Summary

Ratites are flightless birds that include the ostrich, emu, rhea, cassowary and kiwi. The adult weight of these birds varied from 2 kg for the kiwi to 130 kg for the ostrich. Ratites are unique in that they lack a crop, and have evolved some form of fibre fermentation in the gastrointestinal tract. While ostriches and rheas are adaptable grazers/browers in nature, the emu is an opportunistic feeder in nature. Kiwis are omnivorous, while the cassowary is the biggest frugivorous bird. Due to domestication of the ostrich, emu and rhea, some information exists on the nutrient requirements and feeding of especially the ostrich. However, diets recommended for ostriches, emus and rheas are based on production of these birds under intensive farming conditions, with the goal to achieve maximum output. This could be unpractical in a zoo situation where the small number of birds cannot be separated into different age classes, each with its own feed formulation. Thus, based on the nutrient requirements of ostriches and emus, a single diet is recommended for all ratites through the life cycle:

Nutrient	Concentration (dry matter basis)
Crude protein (g/kg)	15.4
Lysine (g/kg)	9
Methionine (g/kg)	3
Calcium (g/kg)	12.5-15
Available phosphorus (g/kg)	3.5-3.9

Although this recommendation will undersupply the amino acid requirements of ostriches up to 300 days of age, it can be justified in that ostriches in zoos are not kept with the aim of maximum growth rate as under intensive farming production. Recommendations for other minerals and vitamins are also included into this formulation, however, no scientific evidence exist to proof the validity of these suggestions. The recommendation is to feed this formulation, made from high quality feed ingredients such as maize meal and oilcake, and the inclusion of a fibre component of at least 15 %, in a pelleted form over age classes to all ratites. However, the evaluation of the performance of birds, especially the digestibility of this diet by different ratites, and the acceptability of the diet, by especially the lesser known cassowary and kiwi, needs attention.