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Nutrition and feeding of ostriches

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Abstract

Dietary habits in the wild and gastrointestinal anatomy and function have established that the ostrich is an herbivore. Ostriches are not turkeys, but turkeys may be the best avian model we have from which to predict the ostrich's nutrient needs. To minimize leg abnormalities in ostrich chicks, it may be helpful to restrict weight gain by limiting dietary protein concentrations below those recommended for starting turkeys and by using higher fiber diets. Non-slip surfaces and exercise also are very important. Egg production by ostriches laying a normal annual clutch does not significantly increase the dietary calcium requirement. When egg production is forced by continually removing eggs, calcium requirements should be met by dietary concentrations of 16 g kg^{-1}. Alternatively, ad libitum access to granulated calcium carbonate or oyster shell could be provided. Until the nutrient requirements of ostriches are better understood, zoos and ostrich farmers with small flocks may find a single life-cycle diet is a rational means to meet nutrient needs and keep feed fresh.

Keywords: Ostrich; *Struthio camelus*; Avian herbivore; Natural diet; Gastrointestinal anatomy; Nutrient requirements; Feeding

1. Introduction

Ostriches (*Struthio camelus*) are the largest living flightless birds in the world. Adult males weigh 100–130 kg, and adult females weigh 90–110 kg (Dunning, 1993). Formerly they were found in Syria and Arabia as well as in Africa, generally south of the Sahara to the Cape Province of the Republic of South Africa. At least six races or subspecies have been described, but one of these is extinct and a second appears to have merged with one of the remaining four races. Now wild ostriches are found primarily in restricted regions of eastern and southern Africa (Brown et al., 1982). Captive ostriches are found in zoos and on farms on six of the seven continents.

An understanding of the natural history of ostriches is helpful in developing a

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successful program of dietary husbandry for ostriches held in captivity. Thus, the following discussion includes descriptions of their historic habitat, environmental adaptability, feeding behavior in the wild, breeding behavior in the wild, gastrointestinal anatomy and function, nutrient requirements, and feeding suggestions.

2. Historic habitat

The preferred habitat of wild ostriches is open short-grass plains and semidesert. In such regions, densities are about one bird to 5–20 km^2. In some African national parks where the birds are protected and there is minimum predation, densities may reach 0.6–0.8 birds per km^2. Ostriches tend to avoid grass taller than 1 m and dense woodland, but they will travel through desert scrub up to 3 m high.

3. Environmental adaptability

Ostriches are well adapted to desert living and in arid regions seem largely independent of free water. However, at artificial waterholes and in captivity, they drink freely and regularly. They are most active in early morning and late afternoon, but are very heat tolerant, and seldom seek shade. Their body temperature may rise appreciably during sun exposure without apparent harm, a useful physiologic adaptation.

4. Feeding behavior in the wild

When feeding, there are alternate bouts of plucking vegetation near ground level with sudden elevations of the head and neck to permit inspection of the surrounding area for signs of danger. Ostriches are almost exclusively herbivorous and are highly selective. They prefer dicotyledonous plants but will eat all parts of forbs and grasses. When available, seed heads of grasses, flowers of Compositae, seed pods of *Aloe* spp., and flowers and seed pods of acacias are chosen. They will also eat fallen figs and may do considerable damage to wheatfields by plucking whole seed heads. Ostriches may eat grasshoppers and locusts when available, but appear not to be dependent upon them. In deserts, they feed on succulent plants when possible, presumably in part for the water provided (Robinson and Seely, 1975).

Captive birds are commonly offered commercial pellets but also feed heavily on alfalfa pastures when available. Dry matter intake of adult captive birds is about 3 kg per day. Small stones are consumed by wild ostriches, and it is assumed that they serve as comminuting gastroliths in the gizzard. Captive birds may consume stones or other foreign objects, some of which may cause injury. Young birds, absent their parents, are curious and naive concerning the danger associated with consumption of certain objects. Access to materials that may be harmful should be limited.

5. Breeding behavior in the wild

Breeding groups in the wild commonly include one territorial adult male per 3–4 females, at least one of which is a "major" female mated to the territorial male in a monogomous bond (Hurxthal, 1979). In much of Africa, most breeding occurs in the dry season, allowing the chicks to hatch before heavy rains begin. The nest site is selected and begun by the territorial male some time before mating. The major female accepts the site, may enlarge the nest, lays her eggs, and incubates her eggs and those laid by "minor" females in the same nest.

Wild major females lay (on alternate days) a clutch averaging 8 eggs (range 5–11), although captive females have laid up to 90 eggs (more commonly < 60) when they were continually removed. Minor females lay an average of 3.7 eggs per clutch (range 2–6). Usually 2–5 minor females lay in the nest of the major female (visiting only briefly), although as many as 18 minor females have been observed at a single nest. The maximum number of eggs that the major female can incubate is about 21 (range 19–25). Thus, the major female's own clutch constitutes less than half of the total. Eggs exceeding the number that can be incubated are ejected and form a ring surrounding the nest. Since major females recognize their own eggs, the ejected eggs are mostly those of minor females (Bertram, 1979).

Average egg weight is about 1500 g (usual range 1300–1900 g), and shell weight is about 20% of egg weight. A single egg is equivalent to about 1.5% of the female's body weight. The egg shell is principally calcium carbonate, and egg shell calcium concentration is about 39–40% (unpublished report, Michigan State University Comparative Nutrition Laboratory).

The major female begins incubation about 16 days after laying her first egg (Siegfried and Frost, 1974). She usually sets on the nest from 1–1.5 h before sunset to 2–3 h after sunrise, and feeds for 3–4 h during daylight. In very hot weather, the male may set on the nest for a period during the day. Incubation continues for 45–46 days, and hatching occupies 3–5 days, although individual chicks escape from the egg in about 9 h.

Chicks hatch with a yolk reserve that amounts to about 25% of their body weight. This is absorbed in 3–4 days, about the time that the chicks can comfortably leave the nest and follow their parents. The age of wild ostrich chicks has been estimated by comparing the height of their back or head to an anatomical point on parent birds

Table 1
Approximate age-related changes in height and appearance of wild ostrich chicks (Brown et al., 1982)

Age	Back height	Head height	Appearance
1 week	33% of parental tarsus height	50% of parental tarsus height	entirely downy
3 week	50% of parental tarsus height	level with parental tibio-tarsal joint	entirely downy
6 week	level with parental tibio-tarsal joint	higher than parental belly	entirely downy
12 week	level with parental belly	below parental back	feather tufts tail and wings
16–20 week	50% of parental size	50% of parental size	feathered, mottled gray and brown, tarsal scutes

Table 2
Approximate age-related changes in weight of captive ostrich chicks (Brown et al., 1982)

Age	Weight (kg)
3 weeks	3
6 weeks	5
10 weeks	10
6 months	45
1 yr	85

(Brown et al., 1982). Guidelines are presented in Table 1. Age-related changes in body weight of captive ostrich chicks are shown in Table 2.

In some parts of Africa, chicks from several clutches form a large creche, containing 100–300 immature birds escorted by adults. These adults accompany the creche for as long as 9 mo, providing protection against predation.

In a study (Hurxthal, 1979) of 27 incubated nests involving 1719 eggs in Nairobi National Park, 1102 eggs (64%) were ejected. Of the 617 eggs that were incubated, 204 chicks (33% of incubated eggs) hatched. No chicks were produced in 8 nests. Thus, 7.6 chicks hatched per incubated nest. Survival to 1 yr was estimated to be 12% or 0.9 per incubated nest. Assuming each incubated nest involved one adult male, one major female, and four minor females, 0.15 young adult was produced per mature adult per year.

6. Gastrointestinal anatomy and function

The digestive tracts of four adult wild ostriches (two males, two females) have been studied (Skadhauge et al., 1984). These ostriches weighed 105–131 kg. The approximate lengths of the various digestive tract segments are shown in Table 3. The large intestine was unusually long (50% of the total digestive tract) for birds, and the proximal 25% was wide and haustrated. A study of the digestive tract of a 30-day-old ostrich chick

Table 3
Lengths of digestive tract segments of adult wild ostriches (Skadhauge et al., 1984)

Digestive tract segment	Length (cm)	Percentage of total
Esophagus	110	4.6
Proventriculus and gizzard	35	1.5
Duodenum	150	6.3
Jejunum and ileum	700	29.2
Cecum	100 [a]	8.4 [a]
Large intestine	1200	50.0
Total	2395 [b]	100.0

[a] Each of 2 ceca was about 100 cm long. The combined lengths of both ceca were used to calculate the percentage of total digestive tract length.
[b] Includes length of both ceca.

established that even in such a young bird the large intestine was over 57% of the length of the combined small and large intestine. The large intestine plus the capacious ceca of the ostrich provide a suitable environment for fermentation of dietary fiber. Many species of anaerobic fermentative bacteria are present, but no ciliate protozoa have been found.

Relatively large concentrations of acetate, lesser concentrations of propionate and butyrate, and trace amounts of isobutyrate, isovalerate, and valerate are present in cecal and large intestinal digesta. Mean particulate retention times in the digestive tracts of young ostriches weighing 7 or 46 kg were 39 or 48 h, respectively, similar to passage rates in sheep.

While reports on direct quantitative measurements of fiber digestibility in the ostrich were not found, it is apparent that this species is well adapted for use of high-fiber diets. Even emus, that have small ceca, a short large intestine, and a short digesta retention time (5.5 h), have a relatively capacious jejunum-ileum, accommodating anaerobic microbial fermentation and digestion of 35–45% of the neutral-detergent fiber (NDF) in diets containing 26–36% NDF (Cho et al., 1984; Herd and Dawson, 1984; Wilson, 1989). The energy released from fiber digestion in the emu was sufficient to support 50% of maintenance requirements (Buttemer and Dawson, 1989; Calder and Dawson, 1978; Dawson and Herd, 1983).

7. Nutrient requirements

While there are many myths concerning the nutritional needs of ostriches, few controlled studies have been conducted (Swart et al., 1987; Van Heerden et al., 1983; Vohra, 1992). It is reasonable to expect that qualitative nutrient requirements would be similar to those of other precocial birds, such as chickens or turkeys. However, it is unlikely that quantitative nutrient requirements would be the same (Robbins, 1993).

An 8-week study (Gandini et al., 1986) was conducted in South Africa in which 20 ostrich chicks (8–10 days old, 894 g mean initial weight) were divided among isocaloric diets (11.30 MJ ME kg^{-1}) providing 140, 160, 180, or 200 g protein kg^{-1}. The diets were fed as a meal ad libitum. Each group of birds was also fed 14.4 kg of freshly cut alfalfa during the 8-week study. Treatment groups were kept in 3×2.5 m outside pens during the daytime and were housed (presumably in a smaller area) at night. It was found that the chicks fed 200 g protein kg^{-1} diet gained weight fastest, and chicks fed 140 g protein/kg diet gained weight slowest, although the differences were not statistically significant ($P = 0.256$) due to the large within-treatment variation (Table 4).

Five ostrich chicks developed leg abnormalities during the 6th and 7th week of the study. Three were from the group fed 200 g protein kg^{-1} diet, and one each were from groups fed 160 and 140 g protein kg^{-1} diet. Hocks were enlarged and/or the tarsometatarsals were bowed. Dietary calcium, phosphorus, and available phosphorus concentrations were 14, 7, and 5 g kg^{-1}, respectively, in all diets, and other nutrient concentrations met or exceeded the nutrient requirements of domestic turkeys. At the end of the 8-week study, all birds were moved into a larger, common enclosure and were fed the diet containing 180 g protein kg^{-1} plus added bonemeal to increase dietary

Table 4
Dietary protein concentration, weight gain, and feed consumption of ostrich chicks from 8–10 days of age for 8 weeks (Gandini et al., 1986) [a]

Item	Dietary protein concentration, g kg^{-1}			
	140	160	180	200
Number of chicks	5	5	5	5
Initial body weight, g				
Mean	912	960	826	876
SD	38	42	68	92
Final body weight, g				
Mean	6350	9400	9580	10010
SD	1519	4516	2924	4672
Range	4550–8000	5800–12000	7200–14200	5000–15750
Body weight gain (8 w), g				
Mean	5438	8440	8754	9134
SD	1539	2507	2957	4606
Diet consumed (8 weeks), g [b]				
Mean	11912	14563	14468	15453
Chicks with abnormal legs	1	1	0	3

[a] All diets contained (by calculation) 11.30 MJ ME kg^{-1}, 68 g crude fiber kg^{-1}, 14 g calcium kg^{-1}, 7 g total phosphorus kg^{-1}, and 5 g available phosphorus kg^{-1}.
[b] This does not include 14.4 kg of green alfalfa fed during the 8-week study to each group. This would add an average of about 700 g of dry matter to the 8-week diet consumption of each bird and would increase dietary protein and calcium concentrations about 10 and 1 g kg^{-1}, respectively.

calcium concentrations to 25 g kg^{-1}. Since bonemeal contains both calcium and phosphorus, the bonemeal supplement would also increase dietary phosphorus concentrations.

While these researchers suggested that the leg abnormalities may have been due to inadequate dietary calcium, their study was not designed to answer this question. It seems unlikely that ostrich chicks 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-fiber, energy-dense diets was responsible.

Meat-type chickens and turkeys have been selected for very rapid growth and early sexual maturity. Male broilers and large-type turkeys reach 80% of adult weight at about 6 mo of age, while male ostriches are about 1 yr old at this stage. Female meat-type chickens begin producing eggs by 22 w, and by 32 w, 80 eggs are produced each day for every 100 hens. Female large-type turkeys produce eggs at a 66% rate by 35 weeks of age. Wild female ostriches are about 2 yr old before egg production begins, and productivity never approaches that of turkeys or meat-type chickens, let alone that of egg-type chickens.

Although the domestic turkey has been used as a model for the ostrich when extrapolating nutrient requirements from the known to the unknown, the hindgut of the turkey is much less suitable as a fermentation vat than that of the ostrich (McLelland, 1975; McLelland, 1979; Stevens, 1988). The combined volume of the jejunum-ileum, large intestine, and ceca is relatively small, and digesta retention time is much shorter (10 h). Thus, the turkey is best fed a granivorous diet, low in fiber. The ostrich, alternatively, is designed for herbivory (Mackie, 1987).

Our experience and that of others (Dinnes, 1972; Flieg, 1973; Fowler, 1986; Fowler, 1993; Riddell, 1981) suggests that the high-protein, low-fiber diets typically fed to young turkeys are likely to lead to leg problems if fed to ostriches. These are seen most often within 8 weeks of hatching, and the abnormalities include swelling of the hocks, bowing of the tibiotarsus and tarsometatarsus, and leg deviations resembling perosis. The latter condition is usually unilateral, involving lateral rotation of the distal tibiotarsus and proximal tarsometatarsus. Occasionally, the gastrocnemius tendon luxates off the medial condyle. The problem is more likely to develop if exercise is restricted, and it is exacerbated by slippery floors and rapid growth rate.

In all long bones of rheas at hatching, pathologists (Reece and Butler, 1984) have observed proximal and distal cartilagenous cones that are attached to the growth plates and extend into the mid-diaphysis. By 10 days the growth plates have nearly separated from the cones, attached only by persistent cartilagenous bridges. By week 3 these cones are evident only in the proximal and distal tarsometatarsus, and by week 6 they have largely disappeared. These cartilagenous cones appear to be normal structures, but the delay in their ossification may increase the susceptibility of young ratite bones to deformation by an accelerated rate of soft tissue accretion.

Although the etiology of these leg problems is not clear (there are no controlled studies demonstrating protection by added manganese, calcium, or phosphorus), use of higher fiber diets that limit soft tissue growth in proportion to skeletal development seems to be helpful. We conducted a study with 39 newly hatched emu chicks at the San Diego Zoo (Ullrey, 1982). They were randomly assigned to 1 of the 4 diets shown in Table 5. All diets contained low metabolizable energy concentrations (9.41–9.83 MJ ME kg^{-1}) compared to starter or grower diets typically fed to turkey poults (11.72–13.81 MJ ME kg^{-1}). Diets 1 and 3 contained 185 g crude protein kg^{-1} vs. 220 g crude

Table 5
Diets fed to emus from hatching to 3 months of age and incidence of leg abnormalities (Ullrey, 1982)

Item	Diet			
	1	2	3	4
Number of emus	9	11	10	9
Metabolizable energy, MJ kg^{-1}	9.83	9.41	9.83	9.41
Crude fiber, g kg^{-1}	80	100	80	100
Protein, g kg^{-1}	185	220	185	220
Lysine, g kg^{-1}	10	12	10	12
Calcium, g kg^{-1}	12	12	16	16
Phosphorus (total), g kg^{-1}	10	10	10	10
Phosphorus (available), g kg^{-1}	8	8	8	8
No. of emus with abnormal legs	1	0	2	0

protein kg^{-1} in diets 2 and 4. Diets 1 and 2 contained 12 g calcium kg^{-1} vs. 16 g calcium kg^{-1} in diets 3 and 4.

The birds were housed by treatment from 1–21 days after hatching in 2×6 m concrete-floored pens covered with indoor–outdoor carpeting. From 21–90 days, they were housed in 4×4 m sand-floored pens. The diets and water were offered ad libitum, and birds that died or developed leg abnormalities were necropsied. No leg abnormalities were seen on diets 2 and 4, while one bird on diet 1, and two birds on diet 3 showed evidence of leg abnormality. At 3 months, all birds were placed on diet 4 until they were sexually mature. Subsequently (and for 12 yr), young and adult ostriches, rheas, and emus at the San Diego Zoo and San Diego Wild Animal Park have been fed a comparable diet as their principal feed source.

8. Feeding suggestions

If diets for ostriches were to be formulated as they have been for domestic poultry, one might expect to have a starter diet, 1–3 grower diets, an adult maintenance diet, and a breeding hen diet. There are two principal reasons why such specificity may be unwarranted. First, our knowledge of the nutrient requirements of this species is so limited that there is barely enough information to formulate a single rational diet. Second, the numbers of any age class that are owned by a zoo or ostrich farmer are generally so few that it is difficult to keep age classes separate, to stock several diets, and to keep the diets fresh. Thus, for many zoos or ostrich farmers, it may 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. Specifications for such a diet are presented in Table 6. This diet can be pelleted and fed ad libitum with water on pasture or in dry lot. Concentrations of protein (essential amino acids) and metabolizable energy in this diet may limit body weight gain somewhat below maximum but are sufficient to support proportional development of the skeleton without excessive soft tissue weight in growing birds.

Adult birds laying many eggs may have a higher dietary calcium requirement than growing birds. If a typical annual clutch of 8 eggs were laid, the amount of calcium incorporated into those egg shells would be the equivalent of 2.6 g per day. Assuming a dietary dry matter intake of 3 kg and 75% utilization of dietary calcium, the dietary calcium requirement for production of 8 egg shells would be increased by 1.2 g kg^{-1}. Since the diet in Table 6 contains 16 g calcium kg^{-1}, more than three times the concentration required by non-laying adult turkeys (5 g kg^{-1}), calcium needs for this low level of egg production would be easily met. If an ostrich hen were induced to lay 60 eggs by removing them as they were produced, using the same assumptions, the dietary calcium requirement for egg shell production would be 8.7 g kg^{-1} greater than the dietary calcium requirement for non-laying birds. If non-laying adult ostriches have the same dietary calcium requirement as non-laying turkeys, it can be calculated that the addition of 8.7 g to 5 g would total 13.7 g calcium kg^{-1} diet, still less than the concentration in the diet in Table 6. While it is unlikely that more calcium would be needed, considering our limited knowledge of nutrient requirements of ostriches,

Table 6
Recommended nutrient specifications for a diet suitable for ostriches, rheas, and emus [a]

Nutrient	Concentration (90% DM basis)
Crude protein, g kg^{-1}	220
Lysine, g kg^{-1}	12
Arginine, g kg^{-1}	13
Methionine, g kg^{-1}	3.5
Methionine + cystine, g kg^{-1}	7
Tryptophan, g kg^{-1}	3
Crude fiber, g kg^{-1}	100
Linoleic acid, g kg^{-1}	10
Calcium, g kg^{-1}	16 [b]
Phosphorus, total, g kg^{-1}	10
Phosphorus, available, g kg^{-1}	8
Sodium, g kg^{-1}	2
Potassium, g kg^{-1}	11
Magnesium, g kg^{-1}	2
Iron, mg kg^{-1}	150
Copper, mg kg^{-1}	20
Zinc, mg kg^{-1}	120
Manganese, mg kg^{-1}	70
Iodine, mg kg^{-1}	1
Selenium, mg kg^{-1}	0.3
Thiamin, mg kg^{-1}	7
Riboflavin, mg kg^{-1}	9
Niacin, mg kg^{-1}	70
Pantothenic acid, mg kg^{-1}	30
Vitamin B_6, mg kg^{-1}	5
Biotin, mg kg^{-1}	0.3
Folacin, mg kg^{-1}	1
Vitamin B_{12}, mg kg^{-1}	0.03
Choline, mg kg^{-1}	1,600
Vitamin A, IU kg^{-1}	8,000
Vitamin D_3, IU kg^{-1}	1,600
Vitamin E, IU kg^{-1}	250
Vitamin K (menadione equivalent), mg kg^{-1}	4

[a] Provide in pelleted form ad libitum with water. Also provide space for exercise on a non-slip surface, e.g., an alfalfa pasture in season. Grit is optional.
[b] This concentration of calcium should be adequate for production of a normal clutch. If eggs are removed to force increased egg production, provide granulated calcium carbonate or oyster shell ad libitum in a separate feeder.

provision of granulated calcium carbonate or oyster shell in a feeder separate from the main diet may be appropriate.

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