NUTRITION OF DOUBLE-WATTLED CASSOWARIES *CASUARIUS CASUARIUS*

J. Sales

PO Box 51, Williston, 8920, South Africa
Email: James_Sales_1@hotmail.com

ABSTRACT

In order to get insight in the captive nutrition of cassowaries, of which some subspecies are endangered, a survey of diets fed to captive cassowaries in zoos worldwide was conducted in October 2004. All zoos responded (n = 13) keep double-wattled cassowaries, and more than 90% of birds are older than 15 months. Diets were based on daily supply of either commercial compound (ratite, dog, poultry, omnivore) diets, or mixtures of fruit and vegetables available, with weekly supplementation of animal (day old chickens, mice, rats) products. Based on a theoretical model applied for domesticated avian species a diet solely based on fruit and vegetables commonly fed in zoos would not supply the maintenance requirement for individual essential amino acids of an adult cassowary of 50kg. However, digestive and physiological adaptations in frugivores species to a nutrient deficient diet is poorly understood. Possible implications, such as 'nutritional disturbance' and 'nutritional imprinting' of captive diets in conservation of the cassowary are discussed.

KEYWORDS

Captive diets, Cassowaries, Casuarius casuarius*, Frugivores, Nutrient requirements*

The family Casuariidae, belonging to the order Struthioniformes, includes three species, namely the One-wattled Cassowary *Casuarius unappendiculatus*, the Dwarf Cassowary *C. bennetti* and the Double-wattled Cassowary *C. casuarius*, with a geographic distribution in New Guinea, adjacent islands and north-eastern Queensland (Howard & Moore, 1991). Several subspecies, with different distribution, habitat and conservation histories are found within each species (Romer, 1997). The Southern Cassowary, *C. casuarius johnsonii*, the largest native vertebrate in the Australian rainforests, is classified as Endangered under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999, with the primary cause of the species' decline in the wet tropics thought to be habitat loss and fragmentation (Queensland Parks & Wildlife Service, 2000). Furthermore, research indicated that, if unmanaged, traditional demand for cassowaries in Papua New Guinea could lead to extirpation of populations (Johnson *et al.*, 2004). Although captive breeding with the Southern Cassowary is not a priority for the purpose of species recovery, such actions may be useful in future when vacated areas are restored and reconnected (Queensland Parks & Wildlife Service, 2000).

Substitutes for wild populations in the development of care and management techniques, demographic and genetic reservoirs, and the last resort for species which have no immediate opportunity for survival in nature, are some of the functions of captive breeding programmes (Conway, 1980). The ultimate goal of such projects, of which the majority is done by the global zoo network, is, despite several limitations (Snyder *et al.*, 1996), to maintain options for re-establishment of natural populations sooner or later. The *ex situ* period should be a transitional stage which enables the species to survive a temporary, critical situation (Jalme, 1999). Nutrition, that is receiving little or no attention, is a critical component in the success of such programmes.

Despite a captive history in European zoos since 1597, cassowaries remain largely unknown to the general public, and are too often a mystery to those zoos which keep them (Perron, 1992). Captive breeding can contribute greatly to education about the role of the wider community in cassowary conservation, and could provide opportunities for studies on the species (Queensland Parks & Wildlife Service, 2000). The precise status of cassowaries in captivity worldwide is a matter of speculation. Although the International Species Information System (ISIS, 2004) maintains a record of those birds kept by its responding zoos, these institutions represent much less than half of the probable total of cassowary keepers.

Whereas some preliminary studies on egg composition (Body & Reid, 1983), incubation (Birchard *et al.*, 1981; Schmitt, 1983; Sapcota, 1999), rearing of chicks (Schmitt, 1983), and general captive husbandry procedures for cassowaries (Whitehead & Masson, 1984; Perron, 1992; Romer, 1997) have been published, literature is fragmented, and very little is known about the nutritional physiology and nutritional needs of cassowaries, even in the wild. A description of the digestive system of the cassowary dated back to 1813, when it was mentioned that the cassowary has larger 'solvent glands' and a stronger 'gizzard' than the emu (Home, 1813), and in 1911, when Beddard disagreed with the statement of Mitchell (1901) that there is no supraduodenal loop between the ileum and duodenum in the cassowary. As obligate frugivores, cassowaries eat fallen fruit and occasionally fruit from branches within reach (Crome, 1976) from over 100 species (Romer, 1997), and play a critical ecological role by dispersing seeds in the rainforest (Pratt, 1982; Stocker & Irvine, 1983; Mack, 1995; Wright, 1998). They digest only the pericarps of fruit, the seeds being excreted whole (Crome, 1976). An apparently gentle digestive mechanism might protect cassowaries from poisonous components in seeds (Stocker & Irvine, 1983), such as cyanogenic plants (Webber & Woodrow, 2004), although a fatal case of oak poisoning has been reported in a captive Double-wattled Cassowary (Kinde, 1988).

Knowledge of amino acid requirements is considered to be of premier importance in animal nutrition due to metabolic factors. Birds are unable to synthesize nine of the 20 amino acids in proteins because of a lack of specific enzymes. Dietary protein must supply sufficient levels of essential amino acids to meet requirements, with enough excess amino acids to supply nitrogen needed to synthesize the nonessential amino acids (Klasing, 1998).

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In an attempt to gain more knowledge about the nutrition of captive cassowaries, a survey was conducted to gather information on diets fed by zoos to birds in their holdings. Also, essential amino acids supplied by diets offered have been compared to the theoretical requirements of the bird.

Materials and Methods

As zoological parks are the only source of captive cassowaries, a survey regarding description of birds, diets and food items, and food quantities offered was sent to zoos in Asia, Australia, Europe and North America holding cassowaries in their collections in October 2004.

The model of Emmans and Fischer (1986) used in domesticated avian species was used to calculate the maintenance requirements for individual essential amino acids (AA_m) of the cassowary as follows:

$$AA_m \text{ (g/day)} = 0.008 \times P_m^{-0.27} \times P \times AAC$$

where 0.008 represents the ideal requirement (8g/unit), P_m(kg) is the potential mature feather-free empty body protein weight, P (kg) is the feather-free empty body protein weight at a specific stage, and AAC is the amino acid content (g/kg protein) in feather-free empty body protein. Essential amino acids needed for body maintenance was assumed to have identical composition as that of the empty body. Maintenance requirements for individual essential amino acids for feathers (g/d) were determined as 1% of that in feather protein weight.

In calculations the following assumptions were used: Mature body weight = 50kg; Feather-free empty body weight = 93% of body weight; Protein content of feather-free empty body weight = 19%; Feather weight = 1.8% of body weight; Feather protein content = 85%.

Assumptions on weight, protein content and essential amino acid content (Table 1) of feather-free empty body and feathers were from data derived with 70 week old (41kg body weight) emus (O'Malley, 1996). These values are in agreement with results obtained with 7 month old (70kg body weight) ostriches (Cilliers *et al.* 1998). As no values were available for tryptophan this essential amino acid has been omitted.

Results

Eleven zoos have supplied information about sex and age of cassowaries in their holdings. The 29 birds kept by the above are all from the species *C. casuarius*, commonly known as the Double-wattled Cassowary. Distribution was as follows: 12 males (4-30 years), 12 females (1.3-30 years), three birds of unknown sex (1.2-2.2 years) and two chicks (3 months). Limited information on body weight was supplied, and ranged from 12 to 55kg for males and 22 to 66kg for females.

Information about feed ingredients and feeding schedule was provided by 13 zoos. Although a wide variety of fruit and vegetables are offered (Table 2), the most common food items offered are apples, bananas, grapes, melons and tomatoes. Mice are offered by eight zoos. Carrots are normally presented in a cooked form, and bananas and different varieties of melon as peeled.

Table 1. Essential amino acid composition (g/kg protein) of feather-free empty body and feather protein determined in 1.4 year old (41kg body weight) emus (O'Malley, 1996).

Amino acid	Feather-free empty body	Feathers
Arginine	68.9	68.0
Cystine	11.2	62.9
Histidine	27.1	5.1
Leucine	71.4	100.3
Isoleucine	34.4	43.2
Lysine	73.3	14.3
Methionine	18.3	2.4
Phenylalanine	48.4	46.1
Threonine	40.4	52.4
Tyrosine	30.1	61.8
Valine	40.6	67.0

A schedule of ingredients offered at different zoos is summarized in Table 3. Six zoos give fruit together with a commercial diet on a daily basis, whereas five rely solely on fruit as the daily diet. No information could be derived on actual intake levels. Amounts of food offered varied from 1.5 to 5kg/bird where only fruit is supplied on a daily basis, to around 1kg when only a commercial diet is offered.

Due to mixtures of fruit and vegetables offered, with proportions unknown, infrequent supply of similar food items on a daily basis, seasonal supply of different items, commercial diets with unknown composition, mixtures of commercial diets and fruit items, and weekly supply of animal products, calculation of dietary nutrient content offered was not conducted. Instead a diet comprising of the five most popular food items (apples, bananas, grapes, tomato and melon) in equal proportions has been constructed. The amount of amino acids (values derived from USDA, 2004) offered by 4kg (wet weight) of this diet (FRUIT), and amino acids supplied by 1kg of a commercial omnivore diet (OMNIVORE), amounts typically offered by zoos to cassowaries and which amino acid composition is available, are compared to the maintenance essential amino acid requirements of an adult cassowary of 50kg body weight (Table 4).

Whereas the constructed diet of fruit and vegetables offered at 4kg per day would supply in only 23 (tyrosine) to 90% (histamine) of maintenance requirements of individual essential amino acids, the commercial diet at 1kg per day would offer a 3.6 (cystine) to 6.4 (methionine) fold over supply.

Discussion

This study illustrates that nutrition of cassowaries in captivity relies on availability of food items, practical experience, and extrapolation of knowledge derived with other ratite species. Fruits and vegetables, very different from what humans would view as dry, tough and tasteless fruit available in the natural habitat of the cassowary, and commercial compound diets formulated according to the dietary requirements of other ratites, avian, dog and omnivore species, are offered. The latter are often constructed for production animals with the parameter of evaluation taken as maximum growth rate. However, the results from this study indicate that most

Table 2. Food items offered by zoos (n = 13) to cassowaries in captivity

Fruit	Zoos	Vegetables	Zoos	Animal products	Zoos	Commercial diets	Zoos	Supplements	Zoos
Apples	10	Beetroot	1	Cheese	2	Dog kibbles	2	Calcium powder	1
Bananas	8	Cabbage	2	Day old chickens	4	Duck pellets	1	Insect pate	1
Cherries	2	Carrots	5	Eggs	2	Omnivore pellets	4	Oyster shell,	3
Grapes	8	Celery	2	Mice	8	Poultry pellets	2		
Kiwi fruit	3	Cucumber	3	Rats	2	Ratite pellets	1		
Mango	3	Lettuce	2						
Melons	8	Onions	1						
Oranges	1	Parsley	1						
Papayas	3	Peas	1						
Pears	7	Peppers	1						
Peaches	2	Potatoes	2						
Pineapples	1	Rice	3						
Plums	3	Spinach	1						
Strawberries	2	Tomatoes	9						

Table 3. Feeding schedule of cassowaries in zoos (n = 13) participating in diet survey

	Daily	Weekly
Fruit and vegetables	11	2
Animal products	2	6
Commercial diets	8	0
Commercial supplements	5	0

cassowaries kept in captivity are well over maturity, where the parameters needed to evaluate diets should concentrate on optimum welfare, health and well being of birds.

According to a model commonly used with domesticated omnivorous avian species, a fruit diet would not meet the maintenance essential amino acid requirements of the cassowary. However, this does not present evidence that a fruit diet is inadequate for feeding of cassowaries. The model used has been developed with omnivorous species that have been domesticated for many years on commercial compound diets. Survival and production on a diet considered nutritionally inadequate because of its low protein content (Moermond & Denslow, 1985), is a common phenomenon in frugivory. This is accentuated by contradictory conclusions (Witmer, 1998; Bosque & Pacheco, 2000) on the efficiency to digest and absorb nitrogen compounds in fruit diets. Several studies (Pryor *et al.,* 2001) have found the maintenance protein requirements of frugivorous birds through nitrogen balances as extremely low in comparison to granivorous species. However, these direct approaches do not account for individual amino acid requirements.

Although evolutionary minimization of nitrogen losses is generally accepted as an adaptation of frugivorous birds (Murphy, 1996) to low protein diets, little is known about digestive and physiological adaptations of frugivores to the nutrients in fruit diets (Witmer & Van Soest, 1998). Whereas omnivorous species such as chickens, quail, rats, pigs and humans are capable of up or down regulating enzymes for amino acid catabolism and are able to utilize diets with either a very low or very high protein content (Koutsos *et al.*, 2001), frugivores select low protein: high carbohydrate diets. The influence of an oversupply of nutrients, as presented by commercial diets formulated according to requirements of omnivore species, are unknown for frugivores. Excess amino acids are degraded to energy, often resulting in fattening, a fact that has to be taken into account in captive environments in zoos that offer limited opportunity for exercise to animals normally highly active in nature. Because of the relationships between different nutrients (Klasing, 1998), it is well known that an oversupply could be more damaging in most cases than a shortage. Furthermore, diets for commercial species are formulated based upon rapid growth in order to obtain maximum economic return from a product, and do not pre-condition the digestive system of an animal to the types of food that it will encounter in the natural environment after release (Thomas, 1997).

Some information is available on food items offered and presentation of items to growing cassowary chicks bred in captivity (Fisher, 1968; Schmitt, 1983). These diets can however be described as 'home-made recipes', based on experience of what is successful, without any similarities between diets. It is well established in animals that pre- or post natal nutritional manipulations may program adult size, metabolism, blood lipids, diabetes, blood pressure, obesity, atherosclerosis, learning, behaviour and life span (Lucas, 1998). This may hold implications for either birds reared in captivity with the aim of release into the wild, or for supplementary feeding of populations in the wild.

This study clearly illustrated the lack of information on nutritional physiology, natural diet composition, and nutritional needs of the cassowary, aspects of critical importance in conservation of these species. Questions arising from this study, in which diets of captive cassowaries was found to rely on 'domestic' fruit and commercial diets, are: (1) can the unique digestive mechanism of the cassowary tolerate the nutrients supplied by diets extrapolated from diets formulated for species other than frugivores, and (2) what would be the result of nutritional imprinting caused by captive diets on nutritional adaptation of birds to diets in the natural environment?

Table 4. Daily amounts of essential amino acids offered and maintenance amino acid requirements.

	Offered (g/d)		Requirement (g/d)
	Fruit	Omnivore	
Arginine	1.5	15.9	3.2
Cystine	0.3	3.3	0.9
Histidine	1.0	5.5	1.1
Leucine	1.1	16.5	3.6
Isoleucine	0.6	9.4	1.7
Lysine	1.4	13.2	3.0
Methionine	0.3	4.7	0.7
Phenylalanine	0.8	9.7	2.3
Threonine	0.8	8.5	2.0
Tyrosine	0.4	6.4	1.7
Valine	0.9	11.4	2.1

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