PRACTICAL DIETS FOR CAPTIVE MONOTREMES AND MARSUPIALS

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SUMMARY

Australian monotremes and marsupials are discussed in relation to their natural feeding habits in the wild, and the extent to which their natural diets can be replaced by commercially available compounded diets in captivity. Some of the more common nutritional problems encountered with captive monotremes and marsupials are also considered.

INTRODUCTION

The aim with feeding all captive wild animals is to group them according to dietary habits, then as far as possible to substitute their natural diet with compounded diets already commercially available. To provide a diverse range of captive animals each with its natural diet is economically not feasible. Some feed companies' in the U.S. specialise in the formulation and production of zoo diets. Some of these diets are very specialised, such as Hallwood's Flamingo Diet (Hume 1977). This compounded diet contains both natural and synthetic sources of pigmentation (shrimp meal and Flaminol respectively) to generate and maintain vivid feather colouration. In Australia the number of zoos, both public and private, is so small that no feed company can market a complete range of specialised zoo diets. This means that authorities housing monotremes and marsupials in 'general have to try to use feeds formulated for domestic species. Often a combination of a domestic formulation and natural food items is the best compromise. In this paper the wide range of dietary habits of Australian marsupials and monotremes is considered in relation to current feeding practices in some zoos.

DIETARY HABITS OF MONOTREMES AND MARSUPIALS, AND CURRENT RECOMMENDATIONS ON FEEDING CAPTIVE ANIMALS

Table 1 contains a simplified classification of extant (still living) Australian monotremes and marsupials, together with some comments on their natural feeding habits.

For the purpose of comparing their natural diets with those used to maintain animals in captivity; it is convenient to group the species into carnivores, omnivores and herbivores. Some families, such as the Dasyuridae, fall 'neatly into one group (in this case carnivory). Other families include species from two dietary groups, such as omnivory and herbivory in the case of the Petauridae. It should also be remembered that the boundaries between carnivory and omnivory, and between omnivory and herbivory, are sometimes difficult to define. Thus many carnivores eat some plant material, either regularly or seasonally when prey species become scarce or unavailable. Conversely, although the tiny Honey Possum (*Tarsipes spencerae*) has a highly specialised long, tube-like mouth and an extensible tongue brushed at the tip that it uses to collect nectar and pollen, its main food items, it also takes small, soft insects, at least in captivity (Vose 1973).

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TABLE 1 A simplified classification of extant Australian monotremes and marsupials, with notes on their natural feeding habits

Species (Common Name)	Typical Mature Body Wt. (kg)	Natural Diet
Monotremes (3 species)		
Ornithorhynchus anatinus (Platypus)	2.5	Crustaceans, molluscs, worms, detritus
Tachyglossus aculeatus (Echidna)	5.0	Ants, termites
Marsupials		
Family Dasyuridae (49 species)		
Sminthopsis crassicaudata (Fat-tailed Dunnart)	0.015	Insects, arachnids
Antechinus stuartii (Brown antechinus)	0.030	Insects, arachnids
Dasyurus viverrinus (Eastern Quoll or Native Cat)	1.0	Insects, lizards, birds, small mammals
Dasyurus maculatus (Tiger Quoll)	2.0	Birds, eggs, reptiles, small mammals
Sarcophilus harrisii (Tasmanian Devil)	10	Small marsupials, wombats, birds, rabbits
Family Notoryctidae (1 species)		
Notoryctes typhlops (Marsupial Mole)	1.0	Insects, earthworms, grass roots
Family Myrmecobiidae (1 species)		
Myrmecobius fasciatus (Numbat)	2.5	Ants, termites
Family Peramelidae (Bandicoots) (18 species)	0.5-1.5	Insects, earthworms, insect larvae, berries, roots
Family Phalangeridae (11 species)		
Trichosurus vulpecula (Brush-tail Possum)	2.5	Foliage, grass, fruit
Phalanger maculatus (Spotted Cuscus)	5.0	Foliage, fruit
Family Burramyidae (7 species)		
Acrobates pygmaeus (Feathertail Glider)	0.050	Nectar, insects
Cercartetus nanus (Eastern Pygmy-possum)	0.060	Pollen, nectar, insects
Family Petauridae (22 species)		
Gymnobelideus leadbeateri (Leadbeater's Possum)	0.15	Acacia gum, manna, honeydew, insects
Petaurus breviceps (Sugar Glider)	0.13	Acacia gum, manna, honeydew, insects
Pseudocheirus peregrinus (Ringtail Possum)	0.8	Foliage, fruit
Schoinobates volans (Greater Glider)	1.5	Eucalypt foliage

TABLE 1 (cont.)

Species (Common Name)	Typical Mature Body Wt. (kg)	Natural Diet
Family Phascolartidae (1 species)		
Phascolarctos cinereus (Koala)	8.0	Eucalypt foliage
Family Vombatidae (3 species)		
Vombatus ursinus (Common Wombat)	30	Grass, grass roots
Lasiorhinus latifrons (Hairy-nosed (Wombat)	30	Grass, grass roots
Family Tarsipedidae (1 species)		
Tarsipes spencerae (Honey Possum)	0.010	Nectar, pollen
Family Macropodidae (56 species)		
Sub-family Potoroinae (Rat-kangaroos)		Non-fibrous plant material (roots, berries, tubers), fungi insects, gum exudates
Aepyprymnus rufescens (Rufous Rat-kangaroo)	2.0	
Potorous tridactylus (Potoroo)	1.5	
Sub-family Macropodinae (Kangaroos and Wallabies)		
Macropus giganteus (Eastern Grey Kangaroo)	35	Grasses, forbs
Macropus rufus (Red Kangaroo)	35	Grasses, forbs
Macropus rufogriseus (Red-necked (Wallaby)	15	Grasses, forbs
Macropus eugenii (Tammar Wallaby)	5	Grasses, forbs
Setonix brachyurus (Quokka)	4	Grasses, succulent shrubs
Thylogale thetis (Red-necked Pademelon)	6	Browse
Wallabia bicolor (Swamp Wallaby)	15	Browse

Carnivores

(i) Platypus This species is difficult to maintain and display in' captivity because of (a) its semi-aquatic life style, and (b) the problem of replacing its natural diet with a commercially available diet. In. the few zoos in which Platypus are kept the diet is normally mainly earthworms and shrimp or yabbies. Mealworms and hard-boiled eggs are occasionally added to the mixture.

(ii) Echidna Although in the wild the diet of the Echidna is not as varied as that of the Platypus, Echidnas are relatively easy to maintain in captivity on ground meat, evaporated cow's milk, yoghurt and minerals and vitamins (Finnie 1978). The yoghurt contains the enzyme lactase, allowing lactose present in the evaporated milk to be utilized. Echidna milk contains very little lactose (Messer and Kerry 1973), and the small intestinal mucosa of Echidnas exhibits negligible lactase activity (Kerry 1969). The most common nutritional problem in captive Echidnas is due to the feeding of excessive amounts of cow's milk. Undigested lactose increases the osmotic pressure in the intestine, causing fluid to enter the gut from the blood. The result is often diarrhoea, dehydration, and death if the situation is not corrected.

(iii.) Dasyurids The smaller dasyurids prey mainly upon insects and spiders, although small rodents may occasionally be taken. In the wild the diet varies seasonally depending upon prey availability. In capativity live mealworms and'locusts or crickets are generally readily accepted, although some species are markedly more fastidious in their dietary preferences than others. Commercial cat foods have been used, but almost always in association with mealworms or crickets.

The larger dasyurids feed'on a range of small mammals, reptiles and birds in the wild. In.captivity a commercial dried cat food usually forms the basis of the diet (up to 80%). This is supplemented with whole laboratory mice and rats, or chickens. Finnie (1978) has reported instances of carnivorous marsupials suffering from nutritional bone diseases when fed red meat or organ meat diets and not supplemented with adequate calcium and vitamin D. The feeding of fish to Tiger Quolls (Dasyurus maculatus) and Eastern Quolls (D. viverrinus) has been associated with symptoms of vitamin A toxicity (Hepatosis dietetica) (Finney 1978). This is due to the high concentrations of vitamin A present in the fish, and is simply solved by removing fish from the diet.

The most common problem in captive dasyurids is obesity, since these marsupials tend to eat everything that is offered. One result of obesity in carnivorous marsupials is often lowered reproductive success, In large species such as the Tasmanian Devil (Sarcophilus harrisii) obesity may cause other problems such as extruded intervertebral discs leading to paraplegia (Finnie 1978). Thus the condition of captive dasyurids must be followed closely and the quantity of food offered modified accordingly.

The other two families of carnivorous marsupials listed in Table 1 contain only one species each, the Marsupial Mole (Notoryctes typhlops) and the Numbat (Myrmeobius fasciatus). Both are very rare species, and therefore have not often been kept in captivity. They are included in the table fcr completeness only.

Omnivores

The omnivores fall into two groups, the bandicoots (Family Peramelidae), and several arboreal species which feed on a mixture of non-foliage plant materials high in sugar content, and arthropods.

(i) Bandicoots The bandicoots all appear to be primarily insectivorous, but the range of feed items reported in the stomach contents and scats (faeces) of bandicoots is broad, including berries, roots, grass and snails as well as arthropods. Consequently bandicoots are easy to maintain in captivity and can be fed on a mixture of cat or dog food (wet or dry), fruit, vegetables and bread. Live insects (crickets and- mealworms) if available are a preferred food item (Bergin 1976). The use of only soft foods (e.g. bread, minced meat, milk) with bandicoots can lead to peridontal disease which is eventually fatal (Munday 1976). Thus they must be provided with at least some harder feedstuffs such as concentrate pellets

(ii) Arboreal species These species feed on animal material in the form of insects, which are high in protein content, and some form of plant exudate high in sugar content, Foliage is not a major food item. The plant exudates include Eucalyptus sap, nectar, Acacia gum, manna and honeydew. Manna is a deposit of white encrusting sugars left where sap has flowed from a wound in the tree trunk or branch produced by sap-sucking insects. Honeydew is the excess sugar which is secreted by sap-sucking insects. In captivity the sugary exudates can be replaced by honey and fruit. Insects such as crickets and insect larvae (e.g. meal-' worms) are usually provided, rather than a commercially prepared cat or dog food.

Herbivores

The herbivores can be divided into the wombats and arboreal folivores, all of which are hindgut fermenters, and the rat-kangaroos,. wallabies and kangarccs, which are all foregut fermenters (Hume 1982).

(i) Hindgut fermenters Wombats. are primarily grazers, and in captivity can be easily maintained on a diet of lucerne or grass hay, together with a grain mixture supplemented with minerals and vitamins.

Among the arbcreal folivores are species such as the Koala (Phascolarctos cinereus) and the Greater Glider (Schoinobates volans) which are strictly folivorous, feeding on only a narrow range of Eucalyptus species. These folivores are not difficult to keep in captivity provided acceptable Eucalyptus foliage is available at all times. Koalas will not accept any other foods. The preferred species of eucalypt include Eucalyptus viminalis (Manna gum), E. punctata (Grey gum), E. camaldulensis (River red gum) and E. tereticornis. Greater Gliders'will drink solutions of honey or sugar if provided along with eucalypt foliage.

Other arboreal folivores such as the Brushtail Possum (Trichosurus vulpecula) and the Ringtail Possum (Pseudocheirus peregrinus) have . broader food perferences in the wild, and in captivity will readily accept a variety of fruits, vegetables, bread, honey, peanut butterand commercial cat food. We have successfully maintained Brushtails on semi-purified diets based on honey, bran, pollard, casein and minerals and vitamins (Wellard and Hume 1981).

(ii) Foregut fermenters The family Macropodidae is divided into two subfamilies, the Macropodinae (the true kangaroos and wallabies) and the Potoroinae (the more primitive rat-kangaroos). The rat-kangaroos typically feed on non-fibrous plant material in the wild, together with fungi and some invertebrate animal material. In captivity they can be maintained on tubers such as sweet potato, dry dog kibble, bread, fruit and vegetables.

On the basis of dentition and from field studies, the kangaroos and wallabies can be divided into browsing, intermediate and grazing grades (Sanson 1978). However, in captivity most species do well on fresh lucerne or lucerne/grass hay together with some crushed grain. In place of the crushed grain Doust and Rabbidge Pty. Ltd. market a Macropod Pellet based on 16% crude protein dairy meal with the addition of a coccidiostat (Amprolium) at 0.5 kg per tonne, and vitamins C, E, B_1, B_2 and B_{12}, pantothenic acid, folic acid, nicotinic acid and choline chloride along with vitamins A and D_3.

The vitamin C is unnecessary, since six macropodine species examined by Birney, Jenness and Hume (1980) all synthesised ascorbate in their liver. In contrast, the vitamin E is included for a good reason. Macropods, especially the smaller wallabies, are susceptible to a nutritional muscular dystrophy. The condition is responsive to supplementation with vitamin E, but not with selenium (Kakulas 1961, 1963a). This is similar to the situation in the rabbit, but opposite to that in sheep and most other animals, in which selenium has been found to be an effective substitute for vitamin E (Underwood 1977). During his studies in Western Australia with Quokkas (Setonix brachyurus) from Rottnest Island Kakulas (1963b) noticed that the smaller the size of enclosure, the higher was the incidence of muscular dystrophy in Quokkas maintained on commercial sheep pellets containing selenium, but not vitamin E. He confirmed this observation in a formal experiment with four animals in enclosures of three different sizes (1.2, 9.0 and 30 sq. m.) replicated four times (Kakulas 1963b); the size of enclosure was an important factor in the development of muscular dystrophy in the Quokka. Apparently the additional stress of crowding increases significantly the vitamin E requirement. In all cases, however, administration of the vitamin was completely effective in preventing paralysis in animals in similar and even smaller enclosures.

We have encountered the same problem in Tammar Wallabies' (Macropus eugenii) and Red-necked Pademelons (Thylogale thetis) maintained for six months on a lucerne hay diet at Armidale, The condition was characterised by muscular weakness and incoordination in the hind legs, and was confirmed histologically as muscular dystrophy. We now feed fresh grass with cracked wheat or sorghum, and have not recorded any instances of muscular problems since.

Coccidiosis, or "black scours", was common among kangaroos at Taronga Zoo prior to 1968 (Finnie 1974). This condition was characterised by profuse black diarrhoea and in the sub--acute form death occurred after 2 to 3 days. In the acute form scant black diarrhoea, often blood-stained, occurred with death ensuing within 24 hours. Medication with Amprolium, a thiamine metabolic antagonist, at 125 ppm of dairy meal was effective in preventing any further deaths at the Zoo due to coccidiosis, and regular faecal examinations have been negative for Eimeria oocysts (Finnie 1974). This is the basis for the inclusion of Amprolium in the Macropod Pellets marketed by Doust and Rabbidge. The Macropod Pellets have been used successfully not only with kangaroos and wallabies, but with rat-kangaroos and wombats as well.

The use of coarse, sharp feeds such as oat awns for macropods should be avoided, since they can cause trauma to the mouth and the tissues can be invaded by the bacteria Fusiformis neurophorus and Corynebacterium pyogenes. The result is often cellulitis and necrosis of the tissues of the mouth, particularly the jaw, and swellings of the mandibles. This latter symptom is responsible for the term "Lumpy Jaw", the common name for necrobacillosis. Although sharp foods should not be used, the provision of long dry grass or fibrous bark for the animals to chew on appears to reduce the incidence of the disease (Bergin 1976).

NUTRITION OF MARSUPIAL YOUNG

Unlike eutherians, lactose is not the predominant carbohydrate in the milk of either monotrems (Messer and Kerry 1973) or macropodid marsupials. (Jenness, Regehr and Sloan 1964). Consistent with this is the low intestinal lactase activity in the macropodid pouch young (Kerry 1969). The diarrhoea commonly observed in suckling macropods reared on cow's milk is no doubt due in most cases to the osmotic effect of undigested lactose in the small intestine. Similarly, the addition of sucrose to milk suckled by pouch young kangaroos causes diarrhoea, since sucrase activity is also extremely low in the small intestine of kangaroos (Kerry 1969). Once the pouch young kangaroo begins to eat significant amounts of grass, which stimulates development of the forestomach microbial fermentation, disaccharide intolerant diarrhoea virtually ceases to be a problem.

Very young orphaned marsupials (kangaroos, Brushtail Possums, wombats) sometimes develop cataracts in the lens of the eye. On the basis of low activities in kangaroo erythrocytes of galactokinase and galactose-l-phosphate uridyl transferase, which convert galactose to glucose, Stephens et al. (1974) suggested that the cataract formation was due to inability to metabolise galactose. In man galactokinase' deficiency galactosaemia results in an accumulation of galactose which is converted in the eye lens to a sugar alcohol which exerts an osmotic effect leading to cataract formation.

Unfortunately Stephens et al. (1974) neglected to assay liver tissue from marsupials for galactose metabolising enzymes. In eutherians the liver is the principal site of both galactokinase and galactose-l-phosphate uridyl transferase. Messer and his colleagues at the University of Sydney have recently demonstrated significant activity of these enzymes in the liver of pouch young Tammar Wallabies. This throws Stephens et al's. (1974) conclusions into doubt. An alternative explanation for the cataract formation in very young orphaned marsupials may be linked to the sudden change from the high CO_2/low O_2 tension environment of the pouch to a relatively high O_2 environment-. Premature children exposed to high O_2 levels in humidicribs occasionally develop' similar symptoms, but this hyphothesis requires testing in ycuny marsupials.

CONCLUSION

The natural feeding preferences of marsupials as a group are diverse. With captive marsupials only limited success has been achieved to date inreplacing their natural diets with complete commercial feeds.. However, many species have been successfully maintained on a combination of natural food items and commercially available compounded feeds formulated for domestic species. Increasing economic pressure in the future may be expected to encourage zoos to increase the use of commercial formulations 'in order to minimise the labour and transport involved in providing some marsupial species with their natural foods.

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