Formulating Diets for Tamandua *(T. tetradactyla)* in Brazilian Zoos

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Diet has long been suspected to be the primary cause of *Tamanduas* inability to thrive in some Brazilian zoos. It is known that free ranging animals consume diets consisting of termites and ants. Unfortunately, little is known about the nutrient requirements of insectivorous species. In addition, incomplete data exist on the nutrient content of many prey species. An assessment of the diet offered tamandua at the Sao Paulo Zoo appeared to indicate a relationship between poor nutrient levels in the diet and malnutrition, poor skin and coat problems, and anemia seen in their collection. A survey of diets fed tamandua in other Brazilian zoos also was conducted. Utilizing products available to Brazilian zoos, a new diet was recommended and has resulted in increased survivability of tamandua in the Sao Paulo Zoo.

Key words: Myrmecophagidae, anteaters, insectivores, nutrition, diet, feeding

INTRODUCTION

Few zoos in North and South America have been successful maintaining and breeding *Tamandua* (Crawshaw and Mehren, 1992; Cassaro, pers. com). In 1992, as a cooperative project between the Milwaukee County Zoo and The Fundacao Parque Zoologico de Sao Paulo, diets offered tamandua were evaluated. Brazilian zoos receive tamandua directly from their native habitat. These animals are considered to be nuisance animals because they wander into public areas. Often the animals received are in poor health. Additionally, their health continues to worsen in captive conditions. Problems encountered in captivity include malnutrition defined as wasting or poor growth, skin and coat problems, and anemia (Cassaro, pers. com). Given that dietary management is crucial to maintaining and propagating any species, in this study, diet was examined as a factor in the poor survivability of tamandua in the Sao Paulo Zoo.

In order to assess the diets of captive Brazilian tamandua, several factors must be considered. These include: the foraging ecology and diet of free-ranging tamandua, quantified data on the nutrient requirements of tamandua or animals most closely related taxonomically which may be applied to tamandua, and food products and items available to institutions holding captive tamandua.

Foraging Ecology

It has been observed that free-ranging tamandua (*T. tetradactyla, T. mexicana)* in Panama and Venezuela consume diets consisting of termites and ants (Montgomery, 1985). They foraged from terrestrial and arboreal sites finding prey by scent and exposing it with strong foreclaws. Tamandua captured and consumed prey with a long highly mobile tongue (Lubin and Montgomery, 1981).

Stomach contents of both *T. mexicana* and *T. tetradactyla* surveyed in Panama and Venezuela contained at least 10 species of 6 genera of termites *(Nasutitermes, Microcerotermes, Armitermes, Leucotermes, Coptotermes, and Calcaritermes)*. Most identifiable termites were *Nasutitermes.* Ant genuses identified differed between *T. tetradactlya* and *T. mexicana.* Among ant species sampled in *T. tetradactyla* stomach contents were *Solenopsis, Formicine, and Camponotus* while *T. mexicana* stomach contents contained *Camponotus, Azteca, and Crematogaster.* Among animals studied, neither species were consistent relative to species of ants consumed or species consumed from day to day. Composition of ant and termite species by caste was not quantified (Montgomery, 1985.)

Little data are available pertaining to the nutrient content of these prey species. In addition, those data available are largely limited to gross components (moisture, protein, fat and ash) (Redford and Dorea, 1984). Few data were found on mineral content (Allen, 1989) and no data exist on amino acid, fatty acid, or vitamin content of prey species.

Available data regarding termite nutrient composition on a dry matter basis (Redford and Dorea, 1984) indicate fat, ash, and nitrogen content vary depending on the species. The largest variation is seen in fat content of termites which not only varies by species but also by reproductive state or caste. Species that tend to be high in ash, tend to be low in fat and nitrogen. *Grigiotermes metoecus,* are geophagus, and consequently are high in ash; 59.9% as a mean for worker and soldiers and low in fat, 1.5%. Alate or reproductive termites tend to be high in fat. Alate nymphs of *Procornitermes araujoi* were 24% fat. Worker and soldier *Armitermes* termites were 42% ash and 3.64% nitrogen while worker and solider *Nasutitermes* worker and soldiers were 10% ash and 7.77% nitrogen.

Nitrogen did not accurately reflect the protein content of invertebrates. It is not appropriate to assume that all the nitrogen in invertebrates is protein nitrogen, however. Nitrogen is present in invertebrates as chitin and other nitrogenous compounds such as uric acid (Allen, 1989). Consequently, unless the nonprotein nitrogen can be quantified, an accurate protein value cannot be determined.

Little work has been done to quantitate the proportion each species and caste of termites and ants contribute to the diet of tamandua. Species have been identified in stomach contents and fecal material (Montgomery, 1985). This coupled with the variation in gross components, especially fat and ash, and the lack of data on the nutrient composition of ants, precludes determining nutrient levels appropriate for captive animals.

Quantified Data on the Nutrient Requirements of Tamandua or Animals most closely Related Taxonomically which may be Applied to Tamandua

Tamandua have been classified in the order Edentata and family Myrmecophagidae. Closely related insectivorous animals within this family include the giant anteater. In North American zoos, giant anteaters offered diets similar to tamandua have not been successful (Crawshaw and Mehren, 1992). Pangolins, or scaley anteaters, order Pholidota, also are not maintained and bred well in captivity (Heath and Vanderlip, 1988). It is apparent that easily extrapable data do not exist.

As a result it may be appropriate to consider the quantified data available on other species that consume animal matter including those species in the order Carnivora. Requirements for many nutrients have been established for dogs, cats, foxes, and minks by the National Research Council and the Association of American Feed Control Officials. These data may provide a range of values to work from. Many of the studies on which requirements are based utilize purified or synthetic diets. Animals fed more practical diets may have different requirements. The Association of American Feed Control Officials recommends nutrient profiles for diets consisting of ingredients commonly used in domestic animal diets.

Food Products and Items Available to Institutions Holding Captive Tamandua

It is not possible to provide captive tamandua with the termites and ants free- ranging animals consume. Brazilian zoos can obtain nests from nearby habitat, however this is labor intensive and has not been shown to result in successful maintenance of the animals.

Brazilian zoos had access to dog biscuits, meats, and vitamin and mineral supplements mainly for humans. Products used may depend largely on the price and nutrient content is variable.

MATERIALS AND METHODS

Diet Evaluation

Medical history of tamandua at the Sao Paulo Zoo was reviewed along with a computer analysis of their diet. At the time of the study the zoo held 2.1 tamandua. For a comparison of products and nutrient levels offered tamandua at other Brazilian institutions, a brief survey about diet composition was conducted which included the following institutions: Brasilia, Rio De Janeiro, Santa Barbara D'Oeste, Belo Horizonte, and Sorocaba. Information exchange was primarily with the Sao Paulo Zoo. Diet recommendations were followed by the Sao Paulo. Consequently results and discussion of the reformulation success will refer exclusively to the Sao Paulo Zoo.

Diet analysis was based on the diets offered animals, not the diets consumed. It is unlikely that sorting, which may affect the nutrient content of the consumed diet occurred to a great extent in most cases because most diets were well mixed and offered as a gruel. However, some diets consisted of different ingredients offered on different days. Many tamandua were also offered termite nests in addition to the mixed diet. The insects and nest material offered and ingested were not possible to quantitate.

The nutrient content of diets offered was calculated using the N-Squared Animal Nutritionist Program (N-Squared Inc., Durango Software, Silverton, Oregon, USA). Nutrient values for products used in Brazilian zoos were obtain from data on feed labels or manufacturers information and entered on the software data base.

Since nutrient requirements for tamandua or insectivores in general are not known, as previously stated, a range of nutrient levels for species in the order Carnivora including dogs, cats, foxes, and minks, was used as a guide for evaluation and recommendation. This range included requirements for reproduction and lactation.

Diet Recommendations

Utilizing products available to Brazilian zoos and a target nutrient range based on species in the order Carnivora, a diet was recommended (Table 2). On an as fed basis the diet contained 57.4% water, 16.4% lean ground beef, 16.4% dry dog food, 4.9% Mead sustagen, and 4.9% banana. Significant changes in the nutrient content of the diet on a dry matter basis included: 1) Lowering the fat from 18% to 13%. 2) Increasing the vitamin E from 12 mg/kg to 49 mg/kg. 3) Increasing niacin from 8 mg/kg to 33 mg/kg. 4) Increasing vitamin B12 from 0.01 mg/kg to 0.02 mg/kg. 5) Increasing magnesium from 0.02% to 0.04%. 6) Increasing iron from 26 mg/kg to 81 mg/kg. 7) Increasing zinc from 27 mg/kg to 84 mg/kg. 8) Increasing copper from 1 mg/kg to 7 mg/kg. Fruits such as banana, are not a food item consumed by free-ranging tamandua. However, since captive animals readily consumed them, fruit remained in the diet at a decreased level. The Sao Paulo Zoo slowly converted their animals to the new diet over 4 weeks. Termite nests were offered twice a week.

Sao Paulo often receives what are termed nuisance animals. These animals are brought to the zoo by the local authorities or the general public. If the animals are healthy they are released into their native habitat. Due to poor success maintaining tamandua in the zoo, it was felt their survivability would be increased if released. To aid in their adjustment to captivity they were slowly converted to the recommended diet. Termite nests were offered daily initially, in addition to the prepared diet. To encourage consumption of the recommended diet, diet ingredients were put on the nest or mixed with nest material. Lean ground beef was introduced first as it was the most palatable ingredient followed by the sustagen, dog food, and banana. Once the animals were consuming the recommended diet, termite nests were offered less frequently. Some animals consumed the recommended diet by their second day in captivity while others took longer up to 11 days in some cases.

Proper preparation and adequate storage of diet ingredients is essential to maintaining healthy animals. Diets ingredients were mixed together well to prevent sorting. In addition, the diet was offered fresh twice a day to avoid spoilage. Guidelines for food sanitation (Educational Foundation for the National Restaurant Association, 1985) were made available and encouraged. Of primary concern to zoos in this climate is high temperatures. Since many dog foods are sprayed with fat to increase palatability, they can become rancid quickly as the fat is broken down. Consequently, feeds easily spoil and mold. Consequently, they have a relatively short shelf life and were not recommended to be purchased in bulk.

RESULTS

Diet Analysis

All diets were of a gruel consistency. Ingredients used include: dog biscuit, beef, milk and milk products, fruits, eggs, bread, Karo syrup, honey, vitamin and mineral supplements (Table 1). Almost each institution used a different dog biscuit. There was a great variation in the vitamin and mineral content in dog foods available to zoos. For example, the iron content of dog foods used in diets ranged from 14 mg/kg to 114 mg/kg; vitamin A from 7 IU/g to 26 IU/g on a dry matter basis. On an as fed basis water or milk/yogurt was the major ingredient in most diets. Commercially available yogurt was not the product referred to in the diets. What is termed yogurt is called "coalhada" in Brazil or "milk that sits out" that has the consistency of yogurt. Nutrient data were not available on "coalhada" so yogurt was used in its place. Items that contributed the most next ranged from bread and fruit to beef and dog food. Vitamin and mineral supplements were used by only 2 of the 6 institutions surveyed.

In general diets, on a dry matter basis, in Brazilian zoos appeared to be low and possibly deficient in one or more nutrients including protein, vitamins, and minerals compared to a target nutrient range for species in the order Carnivora (Table 2). The diet offered at the Sao Paulo Zoo appeared to possibly be in excess of fat, 18%, as did other zoos surveyed with a mean of 16% fat compared to a target range near 9% fat. The levels of vitamin E, niacin, vitamin $B_{12'}$ biotin, sodium, and copper appeared low in Sao Paulo's diet in comparison to the means of other institutions and a target nutrient range. These levels for Sao Paulo, means of other institutions, and target range were respectively, 12 mg/kg, 33 mg/kg, and 28-57 mg/kg for vitamin E; 8.1 mg/kg, 27 mg/kg, and 10-60 mg/kg for niacin; 0.01 mg/kg, 0.03 mg/kg, and 0.02- 0.03 mg/kg for vitamin B12; 0.04 mg/kg, 0.2 mg/kg, and 0.07-0.13 mg/kg for biotin; 0.1 %, 0.4%, and 0.2-0.3% for sodium; and 1.4 mg/kg, 7.3 mg/kg, and 5-8 mg/kg for copper. Both the levels of magnesium, potassium, iron, and zinc appeared low in the diet offered at Sao Paulo and in other institutions compared to the target nutrient range. These levels for Sao Paulo, and the means of other institutions, and a target range were respectively; 0.02%, 0.04%, and 0.05-0.08% for magnesium; 0.4%, 0.5%, and 0.6% for potassium; 26 mg/kg, 50 mg/kg, and 80-90 mg/kg for iron; and 27 mg/kg, 52 mg/kg, and 75-137 mg/kg for zinc.

Diet Recommendations

Diet recommendations as presented in materials and methods were followed by the Sao Paulo Zoo. The diet is offered twice a day to prevent spoilage. It is offered at 9 AM and 3 PM; more food is consumed at the afternoon feeding. Animals are no longer wasting away and dying by 6 months in captivity. Since Sao Paulo Zoo has changed their diet, they have been able to establish a breeding program. Young animals have reach sexual maturity and reproduced successfully. They currently hold 3.4.2 animals.

DISCUSSION

Low levels of vitamin B_{12} iron, zinc, magnesium, vitamin E, niacin, biotin, potassium, sodium, and copper, together with a possible excess level of fat, compared to a range of nutrient requirements for species that consume animal matter, in the diet of tamandua in the Sao Paulo Zoo probably contributed to their failure to survive. Animals received in good condition may not have been able to thrive and reproduce on diets with marginal or borderline nutrient levels. Also, such diets would not be adequate for recuperation and survival of animals received in poor condition.

Low levels of vitamin B_{12} and iron in the diet may have led to anemia. Zinc also appeared low possibly corresponding with many reports of poor skin condition. Other nutrients low in the diet including vitamin E, niacin, biotin, copper, potassium and sodium, may also have contributed to dermatitis, dry skin, rough coats and poor condition in general. It is not surprising poor growth and body condition or wasting was reported. Many of the nutrients reported as low, by themselves would not support adequate growth, and when in combination with others would contribute to the failure to thrive. Since the original diet does not appear to be adequate to support maintenance animals, reproduction would not be expected. Low levels of nutrients in the diet may have been further exacerbated by the possibly high level of fat in many of the diets. If the animals ate to meet their energy needs, intake of protein, vitamins, and minerals may have become limited. In addition, excess fat may have bound minerals such as calcium limiting absorption. A low level of zinc may have led to bone malformities though little data indicate skeletal problems.

The use of milk and milk products which are low in iron, copper, zinc, niacin, and fat soluble vitamins probably contributed to the poor health of the animals. Historically diets for insectivorous mammals have included milk (Meritt, 1975). While milk is a good source of protein, calcium, phosphorus, magnesium, sodium, and potassium, the lactose content does not seem appropriate for insectivorous species. Young mammals have the enzyme lactase necessary to digest milk which, as they get older, decreases in activity. Consequently, tamandua would not be expected to have the ability to digest lactose in the diet. This condition may lead to gastrointestinal distress.

Careful evaluation and/or comparison of nutrient levels in dog foods is essential in offering appropriate diets. An evaluation of dog foods used by Brazilian zoos showed a large range of nutrient levels. Consequently, a range of nutrient values for a dog food or a nutritionally complete feed must be specified in making recommendations.

The' recommended diet was formulated using products available to Brazilian zoos. Fruit and milk products were reduced. Availability of ingredients as well as their proper storage, and preparation, are essential to offering appropriate diets and were considered and outlined.

The recommended diet is one step in offering tamandua in captivity appropriate diets. The extrapolation of data on the nutrient requirements of species in the order Carnivora for insectivores may provide a possible range of nutrient levels until better data are available. Better data include the quantification of diets of free-ranging animals through all seasons. It is necessary to not only collect and analyze insects consumed by tamandua but also determine what proportion each insect species, and caste, contributes to the total diet since nutrient content differs by species and caste. In addition, possible extraneous sources of nutrients such as those obtained from incidental ingestion of insect nest material or soil should be better examined. In addition, collection of blood and tissue levels of amino acids, fatty acids, vitamins and minerals of free-ranging animals is needed to assess the appropriateness of recommended diets in captivity. Providing appropriate diets for animals includes not only nutritional considerations for animals in captivity but also nutritional considerations for those recently removed from their native habitat, as well as those animals to be introduced back into their native habitat.

It is essential to work in country of origin to better understand nutrient and husbandry needs of animals. Through the Sao Paulo Zoo, tamandua recently removed from their natural habitat, were converted to a captive diet and maintained in good condition. Since this project concluded the Sao Paulo has continued to work extensively with tamandua and maintain them successfully.

CONCLUSIONS

1. Tamandua received at the Sao Paulo Zoo failed to thrive, often dying by 6 months in captivity. Animals had poor skin and coat condition and anemia.
2. Diet evaluation indicated low levels of vitamins, and minerals, coupled with a possibly high level of fat in the diet compared to quantified requirements for species consuming animal matter in the order Carnivora, was most likely a factor the animals' poor survivability.
3. Reformulation of the diet to better meet the needs of species consuming animal matter resulted in better health and survivability of tamandua at the Sao Paulo Zoo.

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TABLE 1. Percent contribution of ingredient in diets fed tamandua in Brazilian zoo on an as fed basis

	Brazilian zoos[a]					
Ingredient	SP	BR	RD	SB	BH	SO
Water	58.3			37.8		69.8
Milk		60.2				
Powdered milk				5.7		
Soymilk						4.6
Soymilk powder	2.5					
Yogurt					56.3	1.0
Dog biscuit	15.4	10.5	7.3	21.7	9.4	11.6
Beef	9.3	12.5	7.8		9.4	7.0
Eggs	4.7	10.5	7.3	10.9	4.7	4.7
Banana	7.0		73.1	23.9	9.4	
Papaya	1.4				9.4	
Sustagen	1.4					0.4
Vitamin supplement						0.1
Mineral supplement					0.7	0.4
Bread		6.3	10.5			
Honey					0.7	
Karo syrup						0.5
Total			100 %			

[a]Brazilian zoos include: Sao Paulo (SP), Brasilia (BR), Rio De Janeiro (RD), Santa Barbara D'Oeste (SB), Belo Horizonte (BH), and Sorocaba (SO).

TABLE 2. Nutrient content of diets fed tamandua in Brazilian zoos on a dry matter basis

Nutrient	Range in diets surveyed[a]	Mean of diets surveyed[a]	Level in Sao Paulo	Target nutrient range[b]	Termites[c]
Nitrogen, %	2.4-4.8	3.8	4.2		3.6-9.8
Protein, %	15-30	24	26	25-40	
Fiber, %	2.3-4.9	3.1	1.2	-	
Fat, %	8.5-22	16	18	9	3.0[d]
Ash, %	5.5-10	8.0	6.6	-	10-42
Vitamin A, IU/g	4.7-8.2	6.0	5.8	6-9	
Vitamin D_3, IU/g	0.32-1.1	0.6	1.0	0.6-0.8	
Vitamin E, mg/kg	12-57	33	12	28-57	
Thiamin, mg/kg	1.9-21	6.6	1.9	1.1-5	
Riboflavin, mg/kg	4.1-12	6.8	3.6	1.6-4	
Niacin, mg/kg	12-104	27	8.1	10-60	
Pyridoxine, mg/kg	1.4-17	7.7	2.8	1.1-9	
Folacin, mg/kg	0.4-0.7	0.6	0.4	0.2-0.8	
Vitamin B_{12}, mg/kg	0.01-0.05	0.03	0.01	0.02-0.03	
Pantothenic Acid, mg/kg	13-23	17	10	5-11	
Biotin, mg/kg	0.003-0.3	0.2	0.04	0.07-0.12	
Calcium, %	0.6-2.2	1.3	1.0	0.4-1.1	
Phosphorus, %	0.3-0.9	0.6	0.7	0.4-0.9	
Magnesium, %	0.01-0.08	0.04	0.02	0.05-0.08	
Potassium, %	0.03-1.1	0.5	0.4	0.6	
Sodium, %	0.05-1.3	0.4	0.1	0.2-0.3	
Iron, mg/kg	23-74	50	26	80-90	
Zinc, mg/kg	34-75	52	27	75-137	
Copper, mg/kg	1-17	7.3	1.4	5-8	
Dry matter, %	20-30	28	25		25-26
[e]ME, kcal/g	3.5-4.3	3.9	4.1		

[a]Calculated values for 5 zoos surveyed (Brasilia, Rio De Janeiro, Santa Barbara D'Oeste, Belo Horizonte, and Sorocaba) except for values for iron, zinc, and copper which were surveyed from 4 zoos.
[b]Target nutrient range includes growing and lactating requirements for dogs (AAFCO, 1994), cats (AAFCO, 1994), foxes (NRC, 1982) and minks (NRC, 1982) at an energy density of 4.0 kcal/ gram dry matter.
[c]Termites consumed by tamandua include a range of values for worker and soldier Armitermes and Nasutitermes. Data from Allen, 1989, and Redford and Dorea, 1984.
[d]Data on Armitermes only, Redford and Dorea, 1984
[e]Metabolizable energy calculated from the proximate analysis by the equation: ME (kcal/g) = [(3.5 X %crude protein) + (8.5 X %crude fat) + (3.5 X %carbohydrates)]/100. Carbohydrates are defined as the nitrogen-free extract or 100 less the total of percentages for crude protein, crude fat, crude fiber, moisture, and ash.

TABLE 3. **Nutrient content of recommended diet for tamandua in Brazilian zoos on a dry matter basis**

Nutrient	Level in the diet	Target nutrient range[a]	Termites[b]
Nitrogen, %	4.32		3.6-9.8
Protein, %	27	25-40	
Fiber, %	4.4	-	
Fat, %	13	9	3.0[c]
Ash, %	8.9	-	10-42
Vitamin A, IU/g	8.1	6-9	
Vitamin D_3, IU/g	0.9	0.6-0.8	
Vitamin E, mg/kg	50	28-57	
Thiamin, mg/kg	3.5	1.1-5	
Riboflavin, mg/kg	5.1	1.6-4	
Niacin, mg/kg	33	4-60	
Pyridoxine, mg/kg	4.3	1.1-9	
Folacin, mg/kg	0.5	0.2-0.8	
Vitamin B_{12}, mg/kg	0.02	0.02-0.03	
Pantothenic Acid, mg/kg	22	5-11	
Biotin, mg/kg	0.37	0.07-0.12	
Calcium, %	1.2	0.4-1.1	
Phosphorus, %	0.6	0.4-0.9	
Magnesium, %	0.04	0.05-0.08	
Potassium, %	0.4	0.6	
Sodium, %	0.1	0.2-0.3	
Iron, mg/kg	81	80-90	
Zinc, mg/kg	83	75-137	
Copper, mg/kg	8	5-8	
Dry matter, %	27		25-26
[d]ME, kcal/g	3.7		

[a]Target nutrient range includes growing and lactating requirements for dogs (AAFCO, 1994), cats (AFFCO, 1994), foxes (NRC, 1982) and minks (NRC, 1982) at an energy density of 4.0 kcal/ gram dry matter.

[b]Worker and soldier termites consumed by tamandua include Armitermes and Nasutitermes. Data from Allen, 1989, and Redford and Dorea, 1984.

[c]Data on Armitermes only, Redford and Dorea, 1984.

[d]Metabolizable energy calculated from the proximate analysis by the equation: ME (kcal/g) = [(3.5 X %crude protein) + (8.5 X %crude fat) + (3.5 X %carbohydrates)]/100. Carbohydrates are defined as the nitrogen-free extract or 100 less the total of percentages for crude protein, crude fat, crude fiber, moisture, and ash.