Zoo Biology 15:509-524 (1996)

Nutrition of the Tamandua: I. Nutrient Composition of Termites *(Nasutitermes* spp.) and Stomach Contents From Wild Tamanduas *(Tamandua tetradactyla)*

Sergio E. Oyarzun, Graham J. Crawshaw, and Eduardo V. Valdes

Metropolitan Toronto Zoo, Scarborough, Ontario, Canada

Arboreal termites *(Nasutitermes* spp.) and stomach contents from tamanduas *(Tamandua tetradactyla)* were collected in central Venezuela during the mid part of the dry season (March) of 1993 and 1994. Nutritional analyses were performed on each caste (workers (n = 3), soldiers (n = 5), and alates (n = 1]), on mixed caste samples (n = 1), and on stomach contents from live (n = 5) and roadkill (n = 5) tamanduas. The chemical analysis, expressed on a dry matter (DM) basis, of termite workers, which constituted the majority of the nest populations, showed the highest crude protein (CP) (67%) and the lowest DM (25%) and fat (2%) values. Ash content varied from a low of 4% in alates to a high of 7% in soldiers. The alates contained substantially higher DM (41%) and fat (40%), which was reflected in a higher caloric value (6.88 kcal/g) (gross energy) [GE]), and relatively less CP (49%). Among the macrominerals, potassium (K) was consistently the highest, with an overall mean value of 0.54%, while the calcium (Ca) and phosphorus (P) levels showed overall means of 0.26% and 0.67%, respectively. Iron (Fe) was the highest among the trace minerals but highly variable (soldiers, 1,000 ppm; alates, 246 ppm; workers, 394 ppm). Differences in the concentrations of vitamin A and E were found among termites castes, with soldiers showing the highest values (20 and 85 µg/g for retinol and a-tocopherol, respectively). Acid detergent fiber (ADF) was lower in the alates (13%) and workers (27%) compared to the soldiers *(35%).* Alates' fat was more saturated (39%), while soldiers and workers had a much higher polyunsaturated fatty acid (PUFA) concentration. In general, similar nutrient profiles were found between the tamandua stomach contents and the overall mean composition of *Nasutitermes* spp. However, stomach contents had much higher ADF, ash, and Fe concentrations (3 1%, 14%, and 2,748 ppm) than termites (25%, 5%, and 652 ppm) but lower CP, fat, GE, and Ca values (51%, 11%, 4.58 kcal/g, and 0.11% vs. 58%, 15%, 6.01 kcal/g, and 0.26% in termites). The relatively low concentrations of Ca in both stomach contents and termites may be indicative of a low requirement in Myrmecophaga compared to other mammalian species. Diets consumed by free-ranging

Received for publication June 30, 1995; final revision accepted June 17, 1996.
address reprint requests to Sergio E. Oyarzun, 1704 Wollaston Court, Pickering, Ontario, Canada L1V 2X1.

tamanduas contained on a DM basis 51% CP, 11% fat, 14% ash, 31% ADF, 4.58 kcal/g GE, 0.11% Ca, 0.41% P, 2.52 μg/g retinol, and 44.3 μg/g α-tocopherol. Duplication of these nutrient profiles might greatly benefit captive health and reproduction of this species.

Key words: Myrmecophaga, anteater, natural diet, nutrients, arboreal termites

INTRODUCTION

Feeding insectivorous mammals in captivity has always presented a significant challenge. Both the nutritional and behavioral requirements must be met. Very little is known about the nutritional needs of these species, and their nutrient requirements and tolerance levels have not been established. Although a few studies have been carried out on the dietary habits of anteaters [Montgomery, 1985a,b; Redford, 1985], information on the chemical composition of the prey foods has been restricted to gross components (moisture, protein, fat, and ash) [Phelps et al., 1975; Matsumoto, 1976; Redford and Dorea, 1984], and no information is available on the mineral, vitamin, amino acid, and fatty acid composition of ants and termites.

Anteaters of the genus *Tamandua* are highly specialized predators, subsisting exclusively on a diet of ants and termites [Lubin and Montgomery, 1981; Montgomery, 1985b]. There are two species: *Tamandua mexicana,* which originates from southern Mexico to northwestern South America, and *T. tetradactyla,* which is distributed from northwestern Venezuela to northern Argentina and Uruguay [Wetzel, 1975].

Tamanduas hunt primarily by scent, moving almost continuously during an active period lasting 8 - 10 hr, searching for prey and stopping to feed infrequently for short periods of time (<1 mm). They are individualistic in the timing of their activity, in their use of different microhabitats and degree of arboreality, and in the species composition of their diet [Lubin et al., 1977; Montgomery and Lubin, 1977; Lubin and Montgomery, 1981; Redford, 1985]. They consume both ants and termites, with an apparent preference for the reproductive and worker castes over the soldier caste [Lubin and Montgomery, 1981].

North American and South American zoos have a poor record at keeping tamanduas. Small numbers have been maintained in captivity for several years, but reproduction is uncommon. Poor survival during earlier years is likely related to their specialized dietary requirements and digestive problems [Meritt, 1975, 1976]. The Metropolitan Toronto Zoo (MTZ) has been successful at maintaining the species for extended periods of time, although no reproduction has occurred and a significant medical problem has been observed in our animals. Three *T. mexicana* arrived at the MTZ in 1981, and one of them is still alive. In 1987, a male showed signs of rear limb paresis and urinary retention, progressing to complete flaccid paralysis. Radiography revealed extensive hyperostosis (excessive growth or thickening of bone tissue) of the thoracic, lumbar, and coccygeal vertebrae.

Radiographs of the other animals revealed similar bone lesions. Two wild caught *T. tetradactyla* were added to the MTZ collection in 1986. Both of these younger animals, normal when first examined, subsequently developed hyperostosis of the axial skeleton. Similar lesions have been observed in tamanduas in European zoos [Dierenfeld et al., 1995] and in tamanduas and the giant anteater in other North American zoological institutions.

The pathological lesions were suggestive of either hypervitaminosis A or D or perhaps excessive calcium (Ca) intake, but interpretation of findings from affected animals was difficult due to the lack of normal biochemical and nutritional data [Crawshaw and Oyarzun, in press].

A recent survey on diets fed to tamanduas and giant anteaters in Brazilian and North American zoos revealed a wide variation in their calculated analysis. On a dry matter (DM) basis, Ca levels ranged from 0.04-2.34%, vitamin A from 0.5-57.3 IU/g, and vitamin D from 0.05-68.8 IU/g [Ann Ward, personal communication].

At MTZ the tamanduas were initially fed a diet similar to that recommended by Meritt [1970], consisting of a mixture of evaporated milk, canned dog food, Gevral protein, and a vitamin-mineral supplement. Subsequently, after presentation of the symptoms, various diet adjustments were introduced, and between 1987 and 1994 they were fed the zoo's carnivore mixture (300 g/animal/day).

This investigation forms part of a series of studies on the physiology and nutrition of tamanduas undertaken by the Animal Nutrition Centre of the MTZ to assess the nutritional status of free-ranging tamanduas. The main objective of the present study was to gather baseline information on the nutrient composition of the natural diet of the tamandua through the collection and chemical analysis of one of its primary foods (termites) and of stomach contents from live and roadkill specimens. New diet recommendations may then be made based on this information, thereby improving survival and reproduction of this species in captivity.

MATERIALS AND METHODS

Capture of Tamanduas

The study was conducted in the central llanos (savannahs) of Venezuela during the mid part of the dry season (March) in 1993 and 1994. The search for live tamanduas was carried out mainly at night from 2100 to 0500 hr in three different habitats according to the vegetation communities. These were a gallery forest and a sparsely vegetated palm savannah on Hato Masaguaral (a cattle ranch located 45 km south of Calabozo, Guárico State) and the savannahs and forests of Hato Piñero, a cattle ranch located near the town of El Baál (Cojedes State).

Some animals were caught by their tails, lifting them up from the ground or from lower tree branches, while others had to be darted to bring them down from the trees. The animals were anesthetized with ketamine (Ketaset; Ayerst, St. Laurent, Quebec, Canada), 11 mg/kg, and xylazine (Rompun, Bayvet, Etobicoke, Ontario, Canada), 0.8 mg/kg IM. Immobilized animals were examined, sexed, weighed, and measured. After samples of blood, hair, and stomach contents were taken and upon recovery from anesthesia, the animals were released at the same capture locations.

Stomach Contents

Stomach contents were collected from five live adult tamanduas captured on Hato Masaguaral. An 82 cm x 6 mm diameter rubber feeding tube (CDMV, Montreal, Quebec, Canada) was passed into the stomach. The contents were flushed with water and aspirated into a 60 ml catheter-tipped syringe (Becton-Dickinson, Mississauga, Ontario, Canada) and transported to the ranch facilities for processing. Excess water was removed, and the contents were stored in cryogenic vials and frozen in liquid nitrogen.

Thirteen carcasses of roadkill tamanduas were obtained along the roads of Guárico, Cojedes, Portuguesa and Lara states, during the 1993 and 1994 study periods. The quality of the carcasses ranged from very fresh to moderately autolyzed, but all had been killed within a 12 hr period. Stomach contents were collected only from five fresh carcasses. The stomachs were removed from the carcasses and dissected and the entire contents emptied into plastic containers, temporarily kept on ice, and subsequently transferred into cryogenic vials. All samples were stored in liquid nitrogen until analysis. Stomach contents from two animals were examined for identification of insect remains. All tamanduas were *T. tetradactyla* except for one road-kill, *T. mexicana,* collected in the area of Maracaibo (Zulia State).

Termite Collection

During the 1993 field study, samples of arboreal termites were taken from two colonies, one on Hato Masaguaral, the other near the town of Acarigua, Portuguesa state. Collection was achieved by slicing a section of the carton nests with a machete, causing the termites to come out and defend the colony. They were then brushed off into temporary plastic containers and subsequently packaged in cryogenic vials and frozen in liquid nitrogen. These two samples were comprised exclusively of nasute soldiers and classified as *Nasutitermes corniger* [Maribel Hernandez, personal communication]. The social behavior of the termites forced us to review our collection methods, as all castes of the termite colony were not represented in our samples.

When a termite nest is disturbed, the nasute soldiers concentrate in great numbers at the site of the break, and the workers disappear into the interior of the nest or the covered trails [Lubin and Montgomery, 1981]. Thus, a different approach was followed in 1994. Entire colonies were collected by removing whole arboreal carton nests (two on Hato Piñero and one on Hato Masaguaral) and transporting them in plastic bags to the ranch facilities. They were then fractioned into small sections from which the termites were shaken or picked with forceps, stored in plastic bags, and cleaned from any debris. Using the distinct morphological characteristics of the members in a termite colony, they were sorted into the different castes (soldiers, workers, alates), separately packaged in cryogenic vials, and preserved in liquid nitrogen until analysis. Only one nest contained mature alates (nest 1 from Hato Piñero). The other two colonies contained predominantly the soldier and worker castes. All termites were alive at the time of freezing.

Termite Nest Material

Nest materials were collected from one of the nests taken on Hato Piñero and one nest from HatoMasaguaral. The nests were broken up into small pieces and packaged in air-tight plastic bags for future analysis.

Chemical Analyses

All termite and stomach content samples were lyophilized (Labconco, Freeze Dryer 18; Labconco Corp., Kansas City, MO). The freeze-dried termite and stomach content samples, as well as the nest material samples, were ground through a 1 mm mesh screen (Tecator Cyclotec Sample Mill; Fisher Scientific, Montreal, Quebec, Canada).

Samples were analyzed for DM, fat, ash, and crude protein (CP) according to the methods of the AOAC [1990]. Gross energy (GE) was determined in an adiabatic bomb calorimeter (Parr Instrument

Company, Moline, IL). Absolute DM determination was done by drying to a constant weight in a vacuum oven at 1000C. The same samples were placed in cellulose thimbles (Whatman, W & R Balston Ltd., London, England) for fat extraction using anhydrous ethyl ether in a Soxhlet extractor.

The dry and fat-free samples were wet-ashed with a mixture of concentrated nitric and perchloric acid. Mineral analysis (Ca, Mg, K, Na, Fe, Zn, Cu, and Mn) was performed by atomic absorption spectrophotometry (Perkin-Elmer model 2380; Perkin-Elmer Corp., Norwalk, CT) [Emerson, 1975]. Phosphorus (P) was determined by the alkalimeter animonium molybdate method [AOAC, 1980]; and selenium (Se) was determined by the Fluorimetric Method [Hoffman et al., 1968] using a Perkin-Elmer model 3000 FluorescenceSpectrometer. Validation of the mineral data was acc9mplished using a standard reference material (bovine liver #1 577a; National Bureau' of Standards, Gaithersburg, MD).

Nitrogen (N) determination was performed using a nitrogen analyzer (Leco Instruments Ltd., Mississauga, Ontario, Canada), and the total N by a factor of 6.25 gave the total CP values. Fatty acid analysis was done in a Hewlett-Packard 5890 Series II gas chromatograph (Hewlett-Packard Co., Avondale, PA). Fatty acid methyl esters were identified by comparison of retention times with standards (Nu-CheckPrep, Elysian, MN) and expressed as percentages of total methyl esters.

Termite and tamandua stomach content samples were hydrolyzed for 24 h with 6 N HC1 at 1100C for the determination of amino acid (AA) levels using the Pico-Tag system (Waters Chromatogrpahy Division, Millipore Corporation, Milford, MA) as described in Sarwar et al. [1988]. The sulphur-containing AA are underestimated because samples were not preoxidized before hydrolysis. The fiber components were determined by using the general methods of Van Soest [1982, 1991].

Retinol and α-tocopherol were analyzed by high performance liquid chromatography (HPLC) using a Varian Vista 5500 Liquid Chromatograph equipped with Vista 402 microprocessor and model 8058 autosampler (Varian Canada Inc., Montreal, Quebec, Canada) as described for feed samples in sections 43 .008 - 43 .013 and 43.064 - 43.068 [AOAC, 1975].

All analyses were performed in duplicate at the Crampton Nutrition Laboratory of McGill University (Montreal, Quebec, Canada), and all calculations were conducted on an absolute DM basis.

RESULTS AND DISCUSSION

Proximate Analysis, Gross Energy, Fiber, and Vitamin Content In Termites

The proximate analysis, GE, fiber fraction, and vitamin contents of the different termite castes (mean ± SEM) expressed on DM basis are presented in Table 1.

The reproductive caste (mature alates) had a considerably higher DM (41.0%) and fat content (40.2%) and a lower ash concentration (3.7%) than the other termite castes, which was also reflected in a higher caloric value (6.88 kcal]g). The fat content of the alates was considerably higher than the fat values reported by Redford and Dorea [1984] for immature alates (nymphs) of four other termite species (range: 19.7 - 24.1%) but quite similar to the fat level (v.3%) found in mature (wings removed) alates of *Macrotermes falciger* [Phelps et al., 1975]. CP content of alates (48.8%) was substantially lower than the

TABLE 1. Proximate analysis, gross energy, fiber and vitamin concentrations in termite *(Nasutitermes* spp.) soldiers, workers, alates, and mixed castes*

Analysis	Soldiers (n = 5)	Workers (n = 3)	Alates (n = 1)	Mixed[a] (n =1)	Overall
Dry matter (%)	30.43 ±2.58	24.70 ± 0.51	41.00	21.29	29.36 ± 4.32
Gross energy (kcal/g)	5.29[b]	—	6.88	5.87	6.01 ±0.46
Crude protein (%)	58.03 ±6.46	66.71 ± 2.70	48.80	59.28	58.20 ± 3.67
Crude fat (%)	11.23 ±4.27	2.21 ± 1.05	40.23	6.50	15.04 ± 8.6
Ash (%)	3.72[c] ±0.34	4.58[c] ± 0.22	3.72	4.42	4.11 ± 0.23
NDF (%)	37.55 ±0.43	—	23.37	30.77	30.56 ± 4.09
ADF (%)	34.81 ±1.08	27.09 ± 0.32	13.02	25.44	25.09 ± 4.51
Cellulose (%)	11.31 ±1.41	—	6.35	11.64	9.77 ± 1.71
Lignin (%)	23.51 ±2.49	—	13.03	15.22	17.25 ± 3.19
ADF-N (%)	1.20[b]	3.54 ± 0.04	3.99	3.91	3.16 ± 0.66
Retinol (µg/g)	20.4[c] ±6.14	n.d.[d]	0.65	1.20	7.42 ± 6.49
α-tocopherol (µg/g)	84.45[c] ±15.71	n.d.[d]	40.44	152.60	92.50 ±32.63

*Means ± standard errors. All values expressed on a dry matter basis. A dash indicates there was not sufficient sample.
[a]Mixed castes; sample contained approximately 90% workers and 10% soldiers.
[b] n = 1.
[c] n = 2.
[d]nd = not detectable amounts.

values for soldiers, workers, and a mixed sample (58.0, 66.7, and 59.3%, respectively) but consistent with those reported for alates of other termite species [Phelps et al., 1975; Matsumoto, 1976].

Termite soldiers had similar DM, CP, Ca, P, and GE value to the larvae of the mulberry silk moth [Frye and Calvert, 1989]. The high CP values as listed in Table 1 may be misleading, since they are derived from measurements of all the N, including that trapped in the chitinous exoskeletons which most probably is not available to the tamandua.

In general, the gross composition (DM, ash, CP, and GE) of the *Nasutitermes* spp. alate caste, as determined in this study (Table 1), is in reasonable agreement with those previously reported by Matsumoto [1976] for alate nymphs of three species of epigeous nest builder termites from West Malaysia (average 44.0% DM, 1.7% ash, 38.0% CP, and 6.8 kcal/g) and the CP (41.8%) and GE (7.6 kcal/g ash-free DM) values of *M. falciger* alates as reported by Phelps et al. [1975].

The workers had the highest CP content (66.7%), followed by the soldiers with a mean CP value of 58.0%. The analysis of the mixed sample *(59.3%* CP), which contained approximately 90% workers, tends to confirm these results. However, these findings are in disagreement with previously reported values for the same genus of termites. Redford and Dorea [1984] found that *Nasutitermes* workers had significantly lower CP content than soldiers (44.6 vs. 52.4%). The same authors also reported that, with the exception of *Cortaritermes silvestri,* the worker caste of all species studied had consistently lower CP levels than soldiers of the same species. Similar findings have been reported by Matsumoto [1976] for epigeal termites from West Malaysia (69.4 vs. 55.8% on an ash-free DM basis for soldiers and workers, respectively). These differences are unexplainable and warrant further investigation.

A very large variability was found in the vitamin content of the different castes (Table 1). The concentration of retinol and a-tocopherol in soldiers was considerablyhigher (20.4 and 84.5 µg/g, respectively) than in the alates (0.7 and 40.4 µg/g), contrary to what may be expected considering the much higher fat concentration in the alates. The reported vitamin values for soldiers were obtained from samples collected during the 1993 field study. It is interesting to note that the analysis performed on the three samples of workers showed no detectable amounts of these vitamins, while the mixed sample (approximately 90% workers) had a retinol value 1.2 µg/g and the highest a-tocopherol value (152.6 µg/g). Considering the small number of samples analyzed, these results should be considered inconclusive and warrant further investigation.

The overall mean retinol (7.42 µg/g) and a-tocopherol (92.5 µg/g) levels rep resent 24,733 IU/kg and 137.8 IU/kg of vitamin A and vitamin E activity, respectively (conversion factors: 0.3 µg retinol = 1 IU; 1 mg α-tocopherol = 1.49 IU). These values exceed the requirements of dogs (5,000 IU and 50 IU/kg DM) and cats (10,000 IU and 80 lU/kg DM) for these vitamins [National Research Council, 1985, 1986] and most likely the needs of the tamandua.

Assays for ascorbic acid were also performed, but no detectable amounts were found in any of the termite or tamandua stomach contents samples.

The assays for fiber [Van Soest, 1982, 1991] have been developed specifically for determination of the fiber fractions in plant materials. Their application for analyzing insect matter is questionable. These fiber fraction values perhaps reflect the complex carbohydrate content of the termite exoskeletons (including chitin) that mimic plant components, but it may also represent a measure of true fiber values of the termites' digestive contents, as these insects feed on wood, a cellulose- and lignin-rich material. The acid detergent fiber (ADF) was lower in the softer bodied alate (13.0%) and worker (27.1%) castes compared to the harder, more schlerotized soldiers (34.8%), consistent with what may be expected (Table 1). The concentration of "lignin" in soldiers was almost double (23.5%) the values of alates and mixed termites (13.0 and 15.2%, respectively).

Mineral Concentrations In Termites

The ash content and the mineral profiles (mean ± SEM) of the different castes of *Nasutitermes* spp. termites, expressed on a DM basis, are shown in Table 2.

Analysis of ash content indicated that the worker caste had a higher ash value (4.6%) than soldiers and alates (3.7%), while the mixed caste sample had a concentration (4.4%) closer to the worker samples (Table 2). The higher ash content of the worker caste is consistent with previous reports [Matsumoto, 1976; Redford and Dorea, 1984]. Redford and Dorea [1984] stated that the probable reason for the differences between castes lies in the feeding biology of termites; since the workers ingest the food and feed the soldiers, the former would be expected to have higher concentrations of indigestible materials and thus a higher ash content.

The absolute ash values of workers and soldiers listed in Table 2 are in disagreement with those previously reported by Redford and Dorea [1984]. These authors reported a considerably higher ash concentration in *Nasutitermes* spp. termite workers and soldiers (11.3 and 8.8%, respectively) and even higher values in six other species of carton nest-builder termites (22.7 and 11.3% for workers and soldiers, respectively), while the mean ash content in two species of geophagous termites was 60.5% for workers and 18.4% for soldiers.

A report on chemical composition of epigeous nest-builder termites by Matsumoto [1976] also

TABLE 2. Mineral content of *Nasutitermes* spp. termites*

Analysis	Soldiers (n=2)	Workers (n=2)	Alates (n=1)	Mixed[a] (n=l)	Overall
Ash, %	3.72b ± 0.34	4.58b ± 0.22	3.72	4.42	4.11 ± 0.23
Macro minerals (%)					
Calcium	0.37 ± 0.1	0.20 ± 0.03	0.24	0.22	0.26 ± 0.04
Phosphorus	0.29 ± 0.04	0.40 ± 0.04	0.36	0.46	0.38 ± 0.04
Magnesium	0.15 ± 0.03	0.13 ± 0.03	0.15	0.13	0.14 ± 0.01
Potassium	0.58 ± 0.02	0.61 ± 0.02	0.37	0.60	0.54 ± 0.06
Sodium	0.06 ± 0.01	0.24 ± 0.02	0.21	0.17	0.17 ± 0.04
Trace minerals (ppm)					
Iron	1,001 ± 736	394 ± 12	246	965	652 ± 194
Zinc	164 ± 16	144 ± 2	184	159	163 ± 8
Manganese	115 ± 27	32 ± 4	37	46	57 ± 20
Copper	33 ± 9	52 ± 14	18	50	38 ± 8
Selenium	0.51 ± 0.18	—	—	—	0.51 ± 0.18

*Means ± standard errors. All values expressed on a DM basis. A dash indicates there was not sufficient sample.
[a]Mixed castes; sample contained approximately 90% workers and 10% soldiers.
[b]n = 3.

indicated much higher ash concentrations in workers (26.0 - 66.0%) than in soldiers (2.0 - 24.0%). The differences were attributed to the fact that epigeal termite workers transport in their alimentary system vast amounts of mineral and organic components of soil to build and maintain their mounds.

The mineral profiles appear to be more consistent among the different termite castes. Potassium (K) was the highest by far among the macro minerals, with Ca values less than half the amount of K, distinctive from vertebrate species with higher Ca and P content. But this is logical, as invertebrates have no bony skeletons. Soldier, worker, and mixed caste K values were almost identical (0.58, 0.61, and 0.60%, respectively), while alates had a lower K concentration (0.37%). The soldier caste had the highest Ca (0.37%) and lowest P concentration (0.29%), providing an adequate Ca:P ratio of 1.28, while the Ca values for the other castes and mixed sample were determined a little over 0.2%, with consistently higher P levels (0.36 - 0.46%), giving poor Ca:P ratios of 0.5 - 0.7. These results indicate that termites alone may be marginally adequate in providing the Ca needs of insectivorous mammals in general and the tamandua in particular.

Iron (Fe) values were the highest among the trace minerals but highly variable. The concentration of this element in the soldier caste (1,001 ppm) was two times higher than Fe content in workers (394 ppm) and exceeded by fourfold the Fe content in the alates (246 ppm) (Table 2).

Manganese (Mn) concentration in soldiers (115 ppm) exceeded by twofold the levels found in the other termite castes. The concentrations of zinc (Zn) and copper (Cu) were less variable among castes, ranging from 144 - 184 ppm and 18 - 52 ppm, respectively. Se levels were determined in only the two samples of soldiers collected in the 1993 field study and averaged 0.51 ± 0.18 ppm (Table 2).

Fatty Acid Profile of Termites

The fatty acid profiles of the lipid fraction in the termite samples indicate that the alates' fat was more saturated (38.6%) than the fat in soldiers (33.5%) and workers (31 .8%),

TABLE 3. Analyzed fatty acid composition of the lipid fraction in *Nasutitermes* spp. termites (mean ± SEM)

Fatty Acid[a] (%)		Soldiers (n = 2)	Workers (n = 2)	Alates (n = 1)	Mixed (n = 1)	Overall
Fat soxhlet (%)		11.23 ± 4.27	2.21 ± 1.05	40.23	6.50	15.04 ± 8.6
Capric	10:0	1.24 ± 0.4	0.53 ± 0.22	0.04	1.05	0.55 ± 0.5
Lauric	12:0	0.43 ± 0.3	1.93 ± 1.78	0.16	0.06	0.11 ± 0.05
Myristic	14:0	4.27 ± 1.64	4.10 ± 0.16	4.89	3.46	4.18 ± 0.71
Myristoleic	14:1(n-7)	1.68 ± 0.58	2.09 ± 0.36	0.19	1.64	0.92 ± 0.73
Palmitic	16:0	7.54 ± 1.23	9.71 ± 0.38	19.15	7.78	13.47 ± 5.69
Palmitoleic	l6:l (n-7)	0.99 ± 0.2	2.11 ± 1.34	1.42	0.64	1.03 ± 0.39
Stearic	18:0	11.81 ± 1.4	12.51 ± 0.67	12.68	12.43	12.56 ± 0.12
Oleic	l8:1 (n-9)	32.63 ± 2.9	48.86 ± 1.81	51.08	44.64	47.86 ± 3.22
Linoleic	l8:2 (n-6)	11.08 ± 1.5	15.05 ± 1.33	8.51	15.29	11.90 ± 3.39
Linolenic	18:3 (n-3)	9.67 ± 0	0.00	0.00	5.17	2.59 ± 2.59
Arachidic	20:0	3.87 ± 0.17	1.66 ± 0.29	1.30	2.02	1.66 ± 0.36
Gadoleic	20:1 (n-11)	1.26 ± 0	0.00	0.20	0.00	0.10 ± 0.1
Arachidonic	20:4 (n-6)	9.20 ± 0.93	0.00	0.05	3.48	1.77 ± 1.72
Behenic	22:0	4.38 ± 4.09	1.40 ± 0.25	0.33	1.52	0.93 ± 0.6
SAT[b]		33.52 ± 3.97	31.82 ± 2.08	38.55	28.32	33.44 ± 5.12
MONO[b]		36.55 ± 3.41	53.06 ± 0.83	52.89	46.92	49.91 ± 2.99
PUFA[b]		29.94 ± 0.56	15.05 ± 1.33	8.56	23.94	16.25 ± 7.69

[a]Fatty acid content expressed as percentages of total methyl esters. Fatty acids are denoted by their common name, number of carbons:number of double bonds, followed by the position of the first double bond relative to the methyl-end (n-).
[b]SAT = sum total percentage of 10:0, 12:0, 14:0, 16:0, 18:0, 20:0, and 22:0; MONO = sum total percentage of 14:1, 16:1, 18:1, and 20:1; PUFA = sum total percentage of 18:2, 18:3, and 20:4.

while soldiers and workers had much higher concentration of polyunsaturated fatty acids (PUFA) (29.9 and 15.1%, respectively) than the alates (8.6%) (Table 3).

Oleic acid was the predominant fatty acid in the lipid fraction, irrespective of the termite class, with an overall average of 47.9 ± 3.2%. The soldiers' fat had the highest concentration of arachidonic acid (9.2%), followed by the mixed caste sample (3.5%), while alates' fat had less than 0.1%. Workers' fat had no measurable amounts of arachidonic acid. However, these results are probably not conclusive, considering the small number of observations.

Amino Acid Profile of Termite Soldiers and Tamandua Stomach Contents

The AA profiles (mean ± SEM) of tamandua stomach contents (n = 4) and termite soldiers (n = 2) are summarized in Table 4. AA assays of termite workers and alates were not done, as no sample was available. The AA profile of *Macrotermes falciger* alates [adapted from Phelps et al., 1975] is included for comparative purposes.

Sample analysis indicated considerable differences in CP content on a DM basis (50.9 vs. 43.7%) between the taniandua stomach contents and the termite soldiers collected in the 1993 field study (Table 4). The tamandua stomach contents also had a much higher CP value than the alates of *M. falciger* (41.8%), as reported by Phelps et al. [1975]. The CP values for the nasute soldiers (43.7%) are much lower than those previously reported for the same kind of termite (5 2.0%) by Redford and Dorea

TABLE 4. Amino acid profile of stomach contents from *Tamandua tetradactyla* as compared to the amino acid content of *Nasutitermes* spp. soldiers and *Macrotermes falciger alates* (mean ± SEM; all values expressed as a percentage of dry matter)

	Stomach contents (n=4)	Termite soldiers[a] (n=2)	***M. falciger*** alates[b] (n=2)
Essential (EAA) (%)			
Arginine	2.47 ± 0.11	1.44 ± 0.03	2.57 ± 0.15
Histidine	1.11 ± 0.08	0.69 ± 0.08	1.28 ± 0.03
Isoleucine	1.65 ± 0.08	0.77 ± 0.05	1.69 ± 0.02
Leucine	3.07 ± 0.14	1.57 ± 0.08	3.12 ± 0.02
Lysine	2.16 ± 0.05	1.09 ± 0.08	2.82 ± 0.06
Methionine	0.29[c] ± 0.02	0.14[c] ± 0.01	0.65 ± 0.02
Phenylalanine	1.15 ± 0.07	0.80 ± 0.01	1.92 ± 0
Threonine	1.90 ± 0.03	1.96 ± 0.18	1.67 ± 0
Valme	2.34 ± 0.08	1.22 ± 0.17	2.26 ± 0
Total EAA	16.14	9.68	17.98
Nonessential (NEAA) (%)			
Alanine	11.32 ± 0.82	2.39 ± 1.15	2.57 ± 0.02
Aspartate	3.43 ± 0.15	2.23 ± 0.27	3.74 ± 0.02
Glutamate	5.58 ± 0.64	3.21 ± 0.37	4.37 ± 0.02
Glycine	2.81 ± 0.15	1.28 ± 0.18	1.90 ± 0.02
Proline	1.62 ± 0.02	0.69 ± 0.01	2.22 ± 0.13
Serine	3.12 ± 0.13	1.76 ± 0.31	1.69 ± 0.02
Tyrosine	2.17 ± 0.15	1.52 ± 0.30	2.74 ± 0.14
Total NEAA	30.05	13.08	19.23
Total AA analyzed, % DM	46.19	22.76	37.21
Total AA as % of CP[d]	90.84	52.14	89.02
EAA/NEAA ratio			
0.54	0.74	0.93	
Crude protein (%)	50.85	43.65	41.80

[a]Samples collected in 1993.
[b]Adapted from original data by Phelps et al. (1975).
[c]Methionine values may be underestimated as samples not subjected to prior oxidative treatment.
[d]CP = crude protein.

[1984] but are within the range (25.0 - 74.0%) reported by the same authors for eight other species of Brazilian termite soldiers and considerably lower than those reported for epigeal termite soldiers (72.0%) from West Malaysia [Matsumoto, 1976].

The CP values are based on determination of total nitrogen (N x 6.25) and include the N present as a component of the insects' exoskeletons (chitin) which may not be available to the animals. Thus, the CP values listed in Table 4 may. not represent a true digestible protein value. The protein quality of a feed is related to the AA pattern and the availability of the AA present in the protein to the digestive process of the animal.

All AA, dispensable and indispensable, was proportionately lower in termite soldiers than in tamandua stomach contents, with the sole exception of threonine, which was almost identical (1.9%) (Table 4). The AA profiles of the tamandua stomach contents and *M. falciger* alates compared relatively well in terms of percentage of CP and of AA analyzed. These two profiles also showed remarkable similarities in the individual AA concentrations, except for the substantially higher level of alanine in the stomach contents (11.3 vs. 2.6%), representing 24.5% of the total AA analyzed value. Alanine concentration was consistently high in all stomach content samples, and, as termites appear to have a much lower content, its presence could be explained as coming from ants and/or nest material, both of which were present in substantial amounts in all tamandua stomach contents examined.

The total AA analyzed values, expressed as percentages of the DM, were much higher in the stomach contents (46.2%) than in the termite soldiers (22.7%), likely due to protein hydrolysis and digestive enzymes. The differences are even more striking when the values are expressed as a percentage of the CP (90.8 vs. 52.14%). The proportion of essential and nonessential AA (EAA/NEAA ratio) indicated a much better profile in the *Nasutitermes* soldiers and *Macrotermes* alates, with 43% and 48% of the total analyzed value being essential AA, compared with only 35% in the stomach contents.

Unfortunately, insufficient samples prevented AA analysis of the other termite castes (workers and alates) which were consistently present in higher proportions than soldiers in all live and roadkill stomach contents collected and examined.

All three essential AA profiles listed in Table 4 are comparable to those recommended for dogs and cats [National Research Council, 1985, 1986], with a possible exception of the sulphur-containing AA.

The two primary factors in defining the quality of a protein feedstuff are AA balance and AA availability. Meat protein is illustrative of a high quality protein, as it has a protein content that is highly digestible and an AA pattern similar to the actual AA requirements of carnivorous species. Phelps et al. [1975] reported that the digestibility of termite protein *(M. falciger* alates) was poor (<50%) compared to that of casein when fed to white rats. However, we can only speculate that the availability of these AA after digestion in the digestive tract of a specialized anteater like the tamandua is probably much higher.

The difference between the true protein content, expressed as the total AA content, and the CP values represents mostly nonprotein nitrogen (NPN) from the insects cuticle or exoskeleton.

Nutrient Composition of Tamandua Stomach Contents vs. Termites

Two samples of stomach contents were examined for identification purposes. The first sample contained 69% ants, 22% termite workers, and 9% termite soldiers. The second sample consisted of 77% termite workers, 18% soldiers, and 5% ants. This sample also contained a substantial quantity of nest material.

The proximate analysis and GE, fiber, mineral, and vitamin concentration in stomach contents from tamandua are compared to the overall nutrient content in termites. The results are summarized in Table 5. All values are expressed on a DM basis.

The values presented in Table 5 indicate a remarkable similarity of the nutrient profiles between stomach contents from *Tamandua tetradactyla* and the overall mean composition of *Nasutitermes* spp. termites except for noticeable differences in the ADF content (31.3 vs. 25.1%) and ash content (13.9 vs. 4.1%) between the tamandua stomach contents and the termites. The lower GE value of the tamandua stomach contents (4.6 kcal/g) was consistent with its higher ash content. The similarities in composition between tamandua stomach contents and termites may indicate that either these comprise their main food source or that other foods (ants) selected by tamanduas have similar compositions.

TABLE 5. Nutrient concentrations in tamandua stomach contents *(Tamandua tetradactyla)* as compared to the overall mean composition of termites *(Nasutitermes* spp.)*

	n	Stomach contents Mean :t: SEM	Termites overall Mean :t: SEM
Drymatter(%)	10	17.77:t:1.14	29.36:t:4.32
Gross energy (kca1/g)	4	4.58 :t: 0.53	6.01 :t: 0.46
Crude protein (%)	10	50.85 :t: 1.64	58.20:t: 3.67
Crude fat (%)	9	11.20 :t 2.89	15.04 :t: 8.60
Neutral detergent fiber (%)	4	32.26 :t: 0.8	30.56 :t: 4.09
Acid detergent fiber (%)	6	31.32 :t: 2.68	25.09 :t: 4.51
Cellulose (%)	4	11.62:t: 1.13	9.77:t: 1.71
ADF-N (%)	6	3.44 :t: 0.53	3.16:t: 0.66
Lignin (%)	4	16.13 :t: 0.77	17.25 :t: 3.19
Ash (%)	9	13.85 :t: 2.72	4.11 :t: 0.23
Calcium (%)	7	0.11 :t: 0.03	0.26 :t: 0.04
Phosphorus (%)	7	0.41 :t: 0.04	0.38 :t: 0.04
Magnesium (%)	7	0.10 :t: 0.01	0.14 :t: 0.01
Potassium (%)	7	0.52 :t: 0.06	0.54 :t: 0.06
Sodium (%)	7	0.29 :t: 0.06	0.17 :t: 0.04
Iron (ppm)	7	2,748 :t: 750	652 :t: 194
Zinc (ppm)	7	190 :t: 22	163 :t: 8
Manganese (ppm)	7	82 :t: 21	57 :t: 20
Copper (ppm)	7	28 :t: 2.68	38 :t: 8
Selenium (ppm)	7	3.75 :t: 2.75	0.51 :t: 0.18
Retinol (IJ.g/g)	5	2.52 :t: 0.73	7.42 :t: 6.49
α-tocopherol (IJ.g/g)	5	44.35 :t: 11 92.	50 :t: 32.63

*All values (mean :t: SEM) are expressed on a DM basis. n = number of observations.

Termite Ca values (0.26%) were much higher than those found in the stomach contents (0.11%), while P was equivalent at 0.4%. K was the highest among the macro minerals at 0.5%, while Fe was predominant among the trace minerals. The concentration of this element in the stomach contents (2,748 ppm) was four times higher than in termites (652 ppm). The relatively low concentration of Ca in both stomach contents and termites may be indicative of a lower requirement for this element in tamandua compared to other mammals.

Retinol and α-tocopherol concentrations in termites (7.4 and 92.5 µg/g, respectively) exceeded by more than twofold the levels in the stomach contents (2.5 and 44.4 µg/g, respectively).

The high ash (13.9%) and ADF (31.3%) and lower CP and fat concentrations in the stomach contents most likely reflect intake of nonfood items of low digestibility.

The mineral profiles, except for Fe and Se, also show great similarity. The higher concentrations of these two minerals in the stomach content samples may be explained either through other sources rich in these elements (soil, nest material).

Fatty Acid Profiles of Tamandua Stomach Contents and Termite Lipids

The data on fatty acid composition of the tamandua stomach content lipids were pooled compared to the overall fatty acid profile of the *Nasutitermes* spp. termites (Table 6). The values indicate that the fat was more unsaturated in termites, with higher levels of 18:1, 18:3, and 20:4(66.2% unsaturated in termites vs. 59.3% in the stomach contents). Fat content in termites was slightly higher (15.0%) than that in the stomach contents (11.2%).

TABLE 6. Fatty acid composition of tamandua *(T. tetradactyla)* stomach contents and termite *(Nasutitermes* spp.) lipids (mean ± SEM)

Fatty Acid[a] (%)		Stomach contents (n = 8)	Overall termites (n = 6)
Capric	10:0	0.66 ± 0.10	0.55 ± 0.50
Lauric	12:0	0.51 ± 0.16	0.11 ± 0.05
Myristic	14:0	2.03 ± 0.19	4.18 ± 0.71
Myristoleic	14:1 (n-7)	0.35 ± 0.10	0.92 ± 0.73
Palmitic	16:0	23.95 ± 2.44	13.47 ± 5.69
Palmitoleic	16:1 (n-7)	2.42 ± 0.71	1.03 ± 0.39
Stcaric	18:0	11.17 ± 1.51	12.56 ± 0.12
Oleic	18:1 (n-9)	41.29 ± 4.18	47.86 ± 3.22
Linoleic	18:2 (n-6)	13.16 ± 1.83	11.90 ± 3.39
Linolenic	18:3 (n-3)	1.05 ± 0.29	2.59 ± 2.59
Arachidic	20:0	1.39 ± 0.17	1.66 ± 0.36
Gadoleic	20:1 (n-11)	0.07 ± 0.07	0.10 ± 0.10
Arachidonic	20:4 (n-6)	0.98 ± 0.32	1.77 ± 1.72
Behenic	22:0	0.49 ± 0.14	0.93 ± 0.60
SAT[b]		40.19 ± 2.48	33.44 ± 5.12
MONO[b]		44.14 ± 3.71	49.91 ± 2.99
PUFA[b]		15.20 ± 2.08	16.25 ± 7.69
Fat soxhlet (%)		11.20 ± 2.89	15.04 ± 8.60

[a]Fatty acid content expressed as percentages of total methyl esters. Fatty acids are denoted by their common name, number of carbons:number of double bonds, followed by the position of the first double bond relative to the methyl-end (n-).
[b]SAT = sum total percentage of 10:0, 12:0, 14:0, 16:0, 18:0, 20:0 and 22:0; MONO = sum total percentage of 14:1, 16:1, 18:1, and 20:1; PUFA = sum total percentage of 18:2, 18:3, and 20:4.

Chemical Analysis of the Carton Nest Material

The chemical composition of the arboreal carton nest material of Nasutitermes spp. Is shown in Table 7. Analysis of the two nest material samples collected at different locations indicated similar values for DM, CP, fat, ash, macro minerals, and GE contents. However, some major differences were found in the trace mineral and fiber fractions. The nest from Hato Masaguaral had twice as much Zn and Mn (43 vs. 24 ppm and 145 vs. 73 ppm, respectively), and a much higher Fe content (912 vs. 247 ppm) than the nest from Hato Piñero. The lignin content in the latter was almost two times higher (71.8% vs. 47.0%). The ADF values were higher than the neutral detergent fiber (NDF) values, for which we have no explanation. These materials contained no measurable amounts of fat. Ca concentration was consistently high in both samples (1.7%), but P levels were very low (0.1%).

The carton nest material of Nasutitermes termites is characterized by a total absence of fat, low protein (7.3%), and very high lignin (59.4%). Although it has a high gross energy (5.3 kcal/g), it probably has little or no feed value for the tamandua. This material was found in all samples of tamandua stomach contents, and it may represent a source of Ca for this species if it is in a digestible form.

TABLE 7. Chemical composition of the carton nest material from *Nasutitermes* spp. termites*

	Nest 4 Hato Piñero	Nest 5 Hato Masaguaral	Mean ± SEM
Drymatter(%)	80.67	81.84	81.26±0.59
Crude protein (%)	8.4	6.17	7.29 ± 1.11
Crude fat (%)	0	0	0
NDF (%)	76.35	50.74	63.55 ± 12.8
ADF (%)	81.22	80.67	80.95 ± 0.28
Cellulose (%)	2.81	2.39	2.60 ± 0.21
ADF-N (%)	1.77	1.33	1.55 ± 0.22
Lignin (%)	71.77	47.02	59.40 ± 12.4
Gross energy (kcal/g)	5.30	5.32	5.31 ± 0.01
Ash (%)	6.87	6.6	6.69 ± 0.09
Calcium (%)	1.77	1.66	1.72 ± 0.06
Phosphorus (%)	0.10	0.09	0.10 ± 0.01
Magnesium (%)	0.3	0.19	0.25 ± 0.05
Potassium (%)	0.62	0.53	0.58 ± 0.04
Sodium (%)	0.02	0.02	0.02 ± 0
Iron (ppm)	247	912	580 ± 333
Zinc (ppm)	24	43	34 ± 9.5
Manganese (ppm)	73	145	109 ± 36
Copper (ppm)	13	9	11 ± 2.2

*All values expressed on a DM basis.

Application of Findings

Since 1987, tamanduas at MTZ have principally been fed the zoo's carnivore ration, which we believe contains excessive quantities of Ca and vitamins for this species. Development and refinement of an improved diet mimicking the nutrient levels identified and reported in this study and based on our own experiences and those of other institutions maintaining tamanduas is being undertaken.

CONCLUSIONS

1. Analysis of the nutrient composition of *Nasutitermes* termites from Venezuela revealed them to be a high protein, moderate fat, variable vitamin, and low mineral resource.
2. Differences in composition were seen between the various termite castes, particularly between alates and the worker/soldier castes. Some values differed from previously reported data.
3. Stomach contents taken from *T. tetradactyla* showed a similar nutrient ctmposition to the overall mean composition of termites, with some exceptions.
4. Diets consumed by free-ranging tamanduas contained 50.9% CP, 11.2% fat, 13.9% ash, 31.3% ADF, 4.58 kcal/g GE, 0.11% Ca, 0.41% P, 2.52 μg/g retinol, and 44.35 μg/g α-tocopherol on a DM basis. Duplication of these nutrient profiles might greatly benefit captive health and reproduction of this species.

ACKNOWLEDGMENTS

This work was funded by the Conservation Fund of the Metropolitan Toronto Zoo. It would not have been possible without the invaluable assistance provided by many people. In particular we would like to recognize Antonio Branger and Edgar Useche (Fundación Branger, Hato Pinero); Tomás Blohm (Hato Masaguaral); Dr. Pedro Trebbau, Esmeralda Mujica, Marian Diaz, and Mary Cruz Lamas (Fundación

Nacional de Pargues Zoológicos y Acuarios de Venezuela); Dr. Carlos Bosque, Maribel Hernandez, and

Maria Teresa Hosque (Universidad Simon Holivar); Ing. Agr. Mariela Romero de Lopez, Dr. José Manuel Pernalete, and the staff of the Parque ZoolOgico Miguel Romero Antoni; Elizabeth Frank (Milwaukee County Zoo); Sue Crissey (Hrookfield Zoo); Anne Ward (Fort Worth Zoo); José Luis Mendes Arocha, Salvador Hoer, Efrain Siso, and Juan Sierra (Profauna, Ministerio del Ambiente y Recursos Naturales Renovables de Venezuela); and Mr. Jesus Coty (Universidad de Maracaibo).

REFERENCES

AOAC. OFFICIAL METHODS OF ANALYSIS OF THE ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS, 12th ed. Washington, DC, Association of Official Analytical Chemists, 1975.

AOAC. OFFICIAL METHODS OF ANALYSIS OF THE ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS, 13th ed. Washington, DC, Association of Official Analytical Chemists, 1980.

AOAC. OFFICIAL METHODS OF ANALYSIS OF THE ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS, 15th ed. Arlington, VA, Association of Official Analytical Chemists, 1990.

Crawshaw, G.J.; Oyarzun, SE. Vertebral hyperostosis in anteaters: Probable hypervitaminosis A and/or D. JOURNAL OF ZOO AND WILDLIFE MEDICINE, 27:158—169, 1996.

Dierenfeld, E.S.; Barker, D.; McNamara, T.S.; Walberg, J.A.; Furr, H.C. Vitamin A and insectivore nutrition. VERH. BER. ERKRG. ZOOTIERE 37:245—249, 1995.

Emerson, R.J. A modification in the official methods for the determination of metals in feeds and fertilizers by atomic absorption spectrophotometry. JOURNAL OF THE ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS 58:158, 1975.

Frye, FL.; Calvert, C.C. Preliminary information on the nutritional content of mulberry silk moth *(Bombyx mori)* larvae. JOURNAL OF ZOO AND WILDLIFE MEDICINE 20:73-75, 1989.

Hoffman, J.; Westerly, R.J.; Hidiroglou, M. Precise fluorimetric microdetermination of selenium in agricultural materials. JOURNAL OF THE ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS 51:1039—1042, 1968.

Lubin, Y.D.; Montgomery, G.G. Defenses of *Nasutitermes* termites (*Isoptera, Termitidae*) against tamandua anteaters (*Edentata, Myrmecophagidae*). BIOTROPICA 13:66—76, 1981.

Lubin, Y.D.; Montgomery, G.G.; Young, OP. Food resources of anteaters (*Edentata:Myrmecophagidae*). I. A year's census of arboreal nests of ants and termites on Barro Colorado Island, Panama Canal Zone. BIOTROPICA 9:26—34, 1977.

Matsumoto, T. The role of termites in an equatorial rain forest ecosystem of West Malaysia. I. Population density biomass carbon nitrogen and calorific content and respiration rate. OECOLOGIA 22:153 - 178, 1976.

Meritt, D.A. Edentate diets currently in use at Lincoln Park Zoo, Chicago. INTERNATIONAL ZOO YEARBOOK 10:136—138, 1970.

Meritt, D.A. The lesser anteater *(Tamandua tetradactyla)* in captivity. INTERNATIONAL ZOO

YEARBOOK 15:41—45, 1975.

Menu, D.A. The nutrition of edentates. INTERNATIONAL ZOO YEARBOOK 16:38-46, 1976.

Montgomery, G.G. Impact of vermilinguas (Cydopes, Tamandua:Xenarthra = Edentata) on arboreal ant populations. Pp. 351—363 in THE EVOLUTION AND ECOLOGY OF ARMADILLOS, SLOTHS, AND VERMLLINGUAS. G.G. Montgomery, ed. Washington, DC, Smithsonian Institution Press, l985a.

Montgomery, G.G. Movements, foraging and good habits of the four extant species of neotropical Vermilinguas (Mammalia: Myrmecophagidae). Pp. 365—377 in THE EVOLUTION AND ECOLOGY OF ARMADILLOS, SLOTHS, AND VERMILINGUAS. G.G. Montgomery, ed. Washington, DC, Smithsonian Institution Press, 1985b.

Montgomery, G.G.; Lubin, Y.D. Prey influences on movements of neotropical anteaters. Pp. 103 – 131 in PROCEEDINGS OF THE 1975 PREDATOR SYMPOSIUM. R.L. Phillips; C. Jonkel, eds. Missoula, MT, University of Montana Printing Department, 1977.

National Research Council. NUTRIENT REQUIREMENTS OF DOGS. Washington, DC, National Academy Press, 1985.

National Research Council. NUTRIENT REQUIREMENTS OF CATS. Washington, DC, National Academy Press, 1986.

Phelps, R.J.; Struthers, J.K.; Moyo, S.J.L. Investigations into the nutritive value of *Macrotermes falciger* (Isoptera:Termitidae). ZOOLOGICA AFRICANA 10:123—132, 1975.

Redford, K.H. Feeding and food preference in captive and wild giant anteaters *(Mymecophaga tridactyla).* JOURNAL OF ZOOLOGY 205: 559 - 572, 1985.

Redford, K.H.; Dorea, J.G. The nutritional value of invertebrates with emphasis on ants and termites as food for mammals. JOURNAL OF ZOOLOGY 203:385—393, 1984.

Sarwar, G.; Botting, H.G.; Peace, R.W. Complete amino acid analysis in hydrolisates of foods and feces by liquid chromatogrpahy of precolumn phenylisothiocyanate derivatives. JOURNAL OF THE ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS 71:1172, 1988.

Van Soest, P.J. NUTRITIONAL ECOLOGY OF THE RUMINANT. Corvallis, OR, 0 & B Books, 1982.

Van Soest, P.J. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. JOURNAL OF DAIRY SCIENCE 74:3583 - 3597, 1991.

Wetzel, R.M. The species of tamandua Gray (Edentata, Myrmecophagidae). PROCEEDINGS OF THE BIOLOGICAL SOCIETY OF WASHINGTON 88:95—112, 1975.