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NUTRIENT CONTENT OF TERMITES (SYNTERMES SOLDIERS) CONSUMED BY MAKIRITARE AMERINDIANS OF THE ALTO ORINOCO OF VENEZUELA

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NUTRIENT CONTENT OF TERMITES (*SYNTERMES* SOLDIERS) CONSUMED BY MAKIRITARE AMERINDIANS OF THE ALTO ORINOCO OF VENEZUELA

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Termites *seri* (especially *Syntermes aculeosus* soldiers) are collected extensively by Makiritare (or Ye'Kuana Indians in the Alto Orinoco) and consumed raw or after soaking in hot water (60°–80°C). They are gathered be means of "termite fishing"

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technique and then transported into a package called kukuruciu made with Musacean (*Phenakospermum sp.*) leaves. The solders of *Syntermes* constitute a food source of great nutritional value: high in proteins and essential amino acids such as trytophan, which is generally limiting in the food insects. Abundant are minerals such as iron and calcium together with micronutrients. Essential fatty acids are well represented. In general, heads of *seri* are better nutritionally featured than thorax and abdomens (not eaten by the Makiritare but comsumed by the Piaroa Indians).

KEYWORDS: termites, *Syntermes* soldiers, Makiritare Indians, nutrient content, Alto Orinoco, Venezuela

INTRODUCTION

Edible insects are a widely exploited food source by many indigenous populations in most regions of the world (DeFoliart, 1989, 1999). More than two thousand insect species and other small invertebrates are utilized in the world as source of food for humans (Ramos-Elorduy, 1997). Hundreds of species of insects have been used as food in sub-Saharan Africa, Asia, Australia, and Latin America. In his study on the Yukpa of Columbia, Ruddle (1973) described the human use of a variety of insects as food. The quantity of nutrients that insects may contribute to human diets can be considerable. For example, Dufour (1987) estimated that among the Tukanoan Indians in the Vaupes region of Columbia insects and other small invertebrates provided up to 12% of the protein from animal sources in the men's diets and 26% in the women's diets during the months of May and June. She also found that during certain times of the year insects contributed as much as 20% of the total animal fat to the diets of these people.

It is important to understand that in those indigenous populations where use of insects as food is not discouraged in the culture, these organisms are used not just during times of shortage of other food items. For instance, various insects are consumed during the rainy season when fish and game become less available. To the contrary, insects are usually prized, sought after and incorporated into the diet whenever they are available. In 1999, Glew and coworkers reported on the amino acid, mineral and trace element, and fatty acid content of the mopane worm that is widely used as a food source

in southern Africa, Zimbabwe and South Africa in particular. While researchers have studied the reversion to less preferred wild foods during famines worldwide (DeFoliart, 1999) regular use of wild foods such as termites, caterpillars, palmworms, etc., has long since persisted as an integral aspect of the combined swidden cultivation and hunting, fishing and gathering among the Makiritare (Paoletti et al., 2000). In the present study, investigators in the United States, Venezuela and Italy collaborated in a similar study of the nutrient value of termites (*Syntermes aculeosus*) that are a consumed by the Makiritare Indians of Alto Orinoco, Venezuela (Paoletti et al., 2000). This paper reports our findings. Most termites included in the diet of many indigenous ethnic groups [such as Maku and Tukanoan from Colombia; Piaroa, Yanomamo and Ye'Kuana (or Makiritare) from Venezuela] belong to the *Syntermes* genus (Paoletti et al., 2001). This genus, of which twenty-three species are known, occurs only in South America (Constantino, 1995).

In the present study we will consider the *S. aculeosus* species collected by Makiritare Indians at the stage of both winged and soldiers. The *Syntermes* soldiers, locally called *seri*, are about 2 cm long. They are gathered by means of the "termite fishing" technique and then inserted by hand into packages (called *kukuruciu*) made with Musacean (*Phenakospermum* sp.) leaves. The Makiritare Indians eat only the head of the soldier termites, whereas many other ethnic groups, such as the Piaroa, utilize the whole organism. Makiritare eat the *seri* (soldiers heads) raw or, after soaking in hot water (60–80°C) accompanied with hot pepper (*Capsicum* sp.) and cassava. *Syntermes* (*seri*) are gathered all times of the year by the "termite fishing technique" of the Makiritare Indians (Paoletti et al., 2000). The *S. aculeosus* soldier constitutes a food source of great nutritional value and is prized as a delicious food, as is the case for termites in other parts of the world (Bodenheimer, 1951; Malaisse and Parent, 1997).

MATERIALS AND METHODS

The termites, *Syntermes aculeosus* soldiers, were collected by M.G. Paoletti, H. Cerda, and F. Torres in Toki (Caño Oreinaru, rio Padamo, Amazonas, Venezuela) on December 5, 1998, and north of

Guatamo, rio Padamo, Amazonas, Venezuela (3° 39' 11.6" North; 0.65° 12' 53.5" West; m 280) on January 16, 1999. The samples from the second location were transported in a nitrogen bomb and then lyophilized when they arrived in Padova.

Lipid Extraction and Fatty Acid Analysis

The dried, powdered specimens were extracted with chloroform: methanol (2:1, vol/vol) as described elsewhere (Chamberlain et al., 1993) and the particulate, non-lipid material was removed by filtration. The total extracted lipid fraction was recovered after solvent removal in a stream of nitrogen. The samples were then redissolved in anhydrous chloroform/methanol (19:1, vol/vol) and clarified by centrifugation at 10,000 × *g* for 10 min. Transmethylation was performed using 14% (w/v) boron trifluoride (BF_3) in methanol (Morrison and Smith, 1964). Fifty nanograms of heptadecanoic acid (internal standard) and a 1 ml aliquot of each sample were transferred to a 15 ml teflon-lined screw-cap tube. After removal of solvent by nitrogen gassing, the sample was mixed with 0.5 ml of BF_3 reagent (15%), placed in a warm bath at 100°C for 30 min and cooled. After the addition of saline solution, the transmethylated fatty acids were extracted into hexane. A calibration mixture of fatty acid standards was processed in parallel.

Aliquots of the hexane phase were analyzed by gas chromatography. Fatty acids were separated and quantified using a Hewlett-Packard gas chromatograph (5890 Series II) equipped with a flame-ionization detector. One to two microliter aliquots of the hexane phase were injected in split-mode onto a fused-silica capillary column (Omegawax; 30 m × 0.32 mm I.D., Supelco, Bellefonte, PA). The injector temperature was set at 200°C, detector at 230°C, oven at 120°C initially, then 120–205°C at 4°C per min, 205°C for 18 min. The carrier gas was helium and the flow rate was approximate 50 cm/sec. Electronic pressure control in the constant flow mode was used. The internal standard (heptadecanoic acid, 17:0) and calibration standards (Nuchek, Elysian, MN) were used for quantitation of fatty acids in the various lipid extracts. Solvents were purchased from EM Science, Gibbstown, NJ. The fatty acid data reported represent the average of three determinations.

Amino Acid Analysis

Two to three mg of each dried termite sample were transferred into a tared glass ampoule. Norleucine, an amino acid not commonly found in proteins, was the internal standard used in all determinations. After 1.0 ml of 6 N HCl was added, the samples were flushed with nitrogen, evacuated, sealed and placed in an oven at 110°C for 24 h. Following hydrolysis, a 10 ml aliquot was withdrawn and subjected to derivatization.

Samples to be used for the determination of cysteine were first oxidized with performic acid [80% formic acid: 30% hydrogen peroxide, 9:1, (vol/vol)] for 18 h at room temperature (Hirs, 1967). Performic acid was removed in an evaporative centrifuge and the samples were hydrolyzed with HCl as described above.

The tryptophan content was determined separately. With regard to the tryptophan analysis, 450 µl of 4.67 M KOH containing 1 % (w/v) thiodiglycol was added to each sample (Hugli and Moore, 1972). Hydrolysis was performed in plastic tubes within an evacuated ampoule at 110°C for 24 hrs. After allowing the hydrolysate to cool, 0.5 ml of 4.2 M perchloric acid and 50 µl of acetic acid were added to neutralize the solution. The samples were mixed thoroughly using a Thermolyne Maxi mixer, chilled on ice, and centrifuged. Fifteen microliters of the supernatant were transferred to 6 × 50 mm glass tubes and dried in a speedvac in preparation for derivatization. Duplicate lysozyme controls were analyzed for quality control purposes.

The samples were dried using 20 ml of ethanol: triethylamine:water (2:1:2, vol/vol) and derivatized with 20 ml phenylisothiocyanate reagent [ethanol:triethylamine:water: phenylisothiocyanate (7:1:1:1 vol/vol)] for 20 min at room temperature. Excess reagent was removed in a speedvac. Derivatized and dried samples were dissolved in 100 µl of equilibration buffer.

Analysis of the amino acids was performed with a Waters C_{18} column (3.9 × 150 mm). The gradient solution was the same as that described by Bidlingmeyer et al. (1984). The solvents utilized were the sodium acetate buffer and acetonitrile (300 ml ACN, 200 ml water, 0.2 ml CaEDTA). Twenty microliter aliquots were injected onto the column. Tryptophan analysis was performed according to Hariharan et al. (1993). Elution of the amino acids was achieved by increasing the acetronitrile concentration in the eluent, causing in-

dividual amino acid to be eluted at predetermined times. Quantitation was achieved by monitoring the absorption of the column at 254 nm and comparing the absorbance of individual peaks with that of the corresponding amino acid standard.

Mineral Analysis

The powdered samples were dried overnight at 110°C. Three replicate aliquots containing approximately 0.1 g of each sample were weighed into 125 ml Phillips beakers and then digested using 20 ml concentrated nitric acid and 1 ml concentrated perchloric acid. The samples were covered with watch glasses and set on a hotplate at 120°C for one hour. The hotplate temperature was then increased to 150°C and the samples were refluxed overnight. The watch glasses were removed and the samples taken to near dryness (approximately 1 ml) at the same temperature. At that point, the samples were removed from the hotplate, treated with 2.5 ml of nitric-perchloric acid (4:1 vol/vol), and a minimal amount of deionized water to rinse down the walls of the beakers. After cooling, the solutions were quantitatively transferred to graduated centrifuge tubes and diluted to 50 ml final volume with deionized water. The samples were analyzed by inductively coupled argon plasma atomic emission spectroscopy (ICP-AES, Jarrel-Ash) for trace metals content as described elsewhere (Yazzie et al., 1994; Kim et al., 1997) and quantified against standard solutions of known concentrations that were analyzed concurrently. This digestion technique makes no attempt to solubilize any silicate-based materials that may be in the samples.

RESULTS

Protein Content and Amino Acid Composition

The protein content of the termite's heads (which is the anatomical part consumed by the Makiritare) was rather high, accounting for 643 mg/g of the dry weight (64% dry weight). This value, equal to the sum of all the amino acids (Table I), was slightly lower than that for the thorax and abdomen; however, in a comparison of the essen-

TABLE I
Amino Acid Content of *seri* Termites (mg/g dry weight)

Amino acid	Seri's head $n = 2$	Seri's thorax and abdomen $n = 2$
asp	53.238 ± 0.181	45.869 ± 7.726
thr	28.574 ± 0.491	33.831 ± 13.790
ser	44.648 ± 6.164	38.214 ± 2.538
glu	80.363 ± 5.972	88.202 ± 37.354
pro	43.121 ± 6.523	37.779 ± 0.022
gly	27.327 ± 1.506	37.676 ± 12.660
ala	61.623 ± 10.988	54.126 ± 0.480
val	41.039 ± 3.669	40.820 ± 8.110
met	8.970 ± 1.056	4.740 ± 0.618
ile	31.860 ± 2.303	34.175 ± 12.431
leu	51.694 ± 1.719	58.531 ± 24.624
tyr	34.762 ± 6.680	26.308 ± 0.959
phe	20.825 ± 1.558	29.931 ± 18.193
his	20.843 ± 1.568	20.954 ± 7.508
lys	41.645 ± 23.426	41.645 ± 23.426
arg	39.575 ± 4.755	43.330 ± 19.416
cys	4.642 ± 0.601	3.194 ± 0.474
trp	7.046 ($n = 1$)	5.821 ($n = 1$)
Total	643.063	646.26

tial amino acid composition of the two samples, the head's proteins were of higher quality. In fact, the chemical index, calculated by comparing the essential amino acid content of the sample protein with that of a WHO standard protein, was rather high, with methionine and cysteine, the sulphur amino acids, being the limiting amino acids (Table II). Interestingly, tryptophan, which is generally limiting in the food insects (DeFoliart, 1989), was present, in adequate amount, in the head portion.

Fatty Acid Content

Table III reports the fatty acid content of the crude (total) lipid fraction of the head and thorax of the termites. Nearly the same amount of fatty acid was isolated from the two sections of the termites. At 1.19–1.35 mg fatty acid/g dry weight this represents a very small

TABLE II
Essential Amino Acid Content of *seri* Termites Compared with the WHO Ideal Protein

Amino acid	*seri*'s heads (% of WHO ideal protein)	*seri*'s thorax and abdomen (% of WHO ideal protein)	WHO ideal protein (g/100 g)
his	171	171	19
ile	177	189	28
leu	122	137	66
lys	112	111	58
met+cys	85	49	25
phe+tyr	137	138	63
thr	131	154	34
trp	100	82	11
val	182	180	35

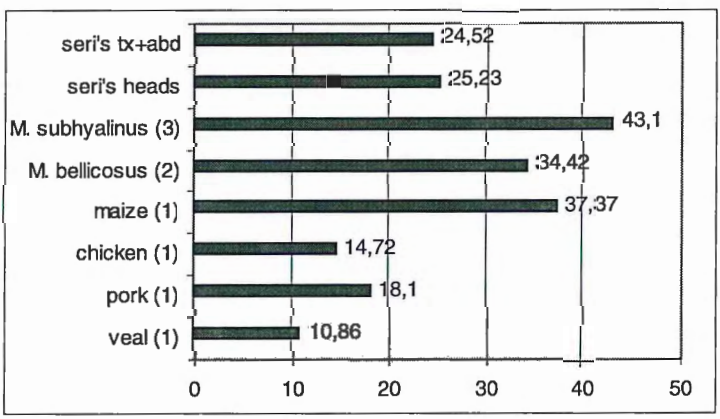

FIGURE 1 Linoleic acid content of *seri* termites, *M. bellicosus, M. subhyalinus* and some common foods (value expressed in % of the total fatty acid). (1) Carnovale and Marletta, 1997; (2) Ukhun and Osasona, 1985; (3) Santos Oliveira et al., 1976.

TABLE III
Fatty Acid Content of *seri* Termites (µg/g dry weight)

Fatty acid	Common name	*seri*'s thorax and abdomen (n = 3)		*seri*'s heads (n = 3)	
		mean	SD	mean	SD
Saturated					
10:0	Capric acid	101	24	182	27
12:0	Lauric acid	15.4	14	ND	
14:0	Myristic acid	129	8	52.6	11
15:0	Pentadecanoic acid	78.5	6.4	56.4	8.5
16:0	Palmitic acid	858	36	777	38
18:0	Stearic acid	1340	20	1300	40
20:0	Eicosandic acid	120	75	74.3	11.3
22:0	Behenic acid	91.4	22.9	91.7	18.4
Subtotal		2733.3		2534	
Monounsaturated					
14:1	Myristoleic acid	26.7	2.4	ND	
16:1	Palmitoleic acid	121	13.5	113	32
18:1 ω-9	Oleic acid	4470	180	5900	140
18:1 ω-7	Vaccenic acid	113	7.6	82.5	14.3
18:1 ω-5	13-Octadecenoic acid	41.9	8.6	18.6	32.3
20:1 ω-9	11-Eicosenoic acid	202	25	85.3	38
22:1 ω-9	Euric acid	99.7	5.1	74.3	15.8
Subtotal		5074.3		6273.7	
Polyunsaturated					
18:2 ω-6	Linoleic acid	2930	180	3420	32
18:3 ω-6	γ-Linolenic acid	20.2	18.4	12.9	22.2
18:3 ω-3	α-Linolenic acid	827	181	933	151
20:2 ω-6	D11,14-eicosadienoic acid	ND		25.6	22.3
20:3 ω-6	Dihomo-g-Linolenic acid	172	9	190	16.4
20:4 ω-6	Arachidonic acid	91.5	23.2	91.7	18.4
20:5 ω-3	Timnodonic acid	99.7	5	74.3	15.8
Subtotal		4140.4		4747.5	
Grand Total		12000		13600	

amount of lipid. Oleic acid accounted for about 40% and 90% of the total and the unsaturated fatty acids in the head and thorax, respectively. The two fatty acids that are essential in humans [linoleic acid (0.342 mg/g) and a-linolenic acid (0.093 mg/g)] were well represented

TABLE IV
Fatty Acid Composition (weight %) of *seri* Termites

Fatty acid	Common name	*seri*'s thorax and abdomen ($n = 3$)	*seri*'s heads ($n = 3$)
Saturated			
10:0	Capric acid	0.9	1.3
12:0	Lauric acid	0.1	0.0
14:0	Myristic acid	1.1	0.4
15:0	Pentadecanoic acid	0.7	0.4
16:0	Palmitic acid	7.2	5.7
18:0	Stearic acid	11.2	9.6
20:0	Eicosandic acid	1.0	0.6
22:0	Behenic acid	0.8	0.7
Subtotal		22.9	18.7
Monounsaturated			
14:1	Myristoleic acid	0.2	
16:1	Palmitoleic acid	1.0	0.8
18:1 ω-9	Oleic acid	37.4	43.5
18:1 ω-7	Vaccenic acid	1.0	0.6
18:1 ω-5	D13-Octadecenoic acid	0.4	0.1
20:1 ω-9	D11-Eicosenoic acid	1.7	0.6
22:1 ω-9	Euric acid	0.8	0.6
Subtotal		42.5	46.3
Polyunsaturated			
18:2 ω-6	Linoleic acid	24.5	25.2
18:3 ω-6	γ-Linolenic acid	0.2	0.2
18:3 ω-3	α-Linolenic acid	6.9	6.9
20:2 ω-6	D11,14-eicosadienoic acid	0.0	0.2
20:3 ω-6	Dihomo-g-Linolenic acid	1.4	1.4
20:4 ω-6	Arachidonic acid	0.8	0.7
20:5 ω-3	Timnodonic acid	0.8	0.6
Subtotal		34.7	35.02
Total		100.00	100.00

proportion-wise in the overall fatty acid composition.

Figures 1 and 2 show the percentages of these two essential fatty acids (relative to the total fatty acids) in the termite samples, in several common occidental foods and other insects, and in two termites

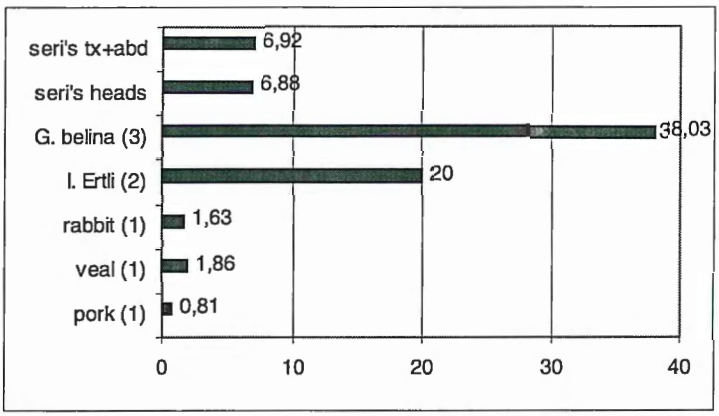

FIGURE 2 α-Linolenic acid content of *seri* termites, *I. ertli*, *G. belina* and some common foods (value expressed in % of the total fatty acid). (1) Carnovale and Marletta, 1997; (2) Santos Oliveira et al., 1976; (3) Glew et al., 1999

and two caterpillars consumed by African populations. Linoleic acid represented, in both the samples (heads and thorax plus abdomen), about 25% of the total fatty acids; this value was higher than for veal (10.9%) and pork (18.1%), but not as high as the percentages found in the lipids of the African termites, *M. bellicosus* and *M. subhyalinus* (34% and 43%, respectively). Also, α-linolenic acid at about 7% was well represented in the termite samples, while the conventional meat, veal, had a value of only 1.86%. The caterpillars *I. ertli* and *G. belina* had the highest a-linolenic acid content (20% and 38%) respectively.

Termites contain nutritionally insignificant amounts of arachidonic acid and docosahexaenoic acid. From these data, it is clear that termites (soldiers) are not a rich source of essential fatty acids, or fat calories.

Mineral and Trace Element Content

The quantities of a number of minerals and trace elements in termites that are nutritionally essential in humans, as well as the content of several toxic elements, are summarized in Table V. The thorax contained relatively large quantities of calcium, and

TABLE V
Mineral Content of *seri* Termites (μg/g dry weight)

Minerals	*seri*'s thorax and abdomen ($n = 3$)	SD	*seri*'s heads (n = 3)	SD
Aluminum	2500	88	2110	344
Arsenic	0.87	0.11	1.07	0.13
Calcium	2300	120	539	75
Chromium	1.39	0.50	1.63	0.75
Copper	23.6	1.2	6.38	1.0
Iron	868	55	1090	229
Potassium	15300	459	8910	1050
Magnesium	1870	100	984	211
Manganese	129	7	35.8	4.5
Molybdenum	ND		ND	
Sodium	661	45	486	81
Nickel	1.01	0.24	0.87	0.14
Phosphorus	5880	267	5520	835
Lead	ND		0.62	0.13
Selenium	ND		ND	
Strontium	16.9	0.9	1.79	0.46
Titanium	58.6	7.9	67.3	18.70
Vanadium	1.09	0.05	1.1	0.1
Tungstenum	1.57	0.24	2.32	0.31
Ittrium	0.42	0.03	0.26	0.09
Zinc	102	3	148.0	21

about four-fold more than the heads. Especially noteworthy were the large amounts of iron in both the termite thorax and abdomen (868 μg/g) and heads (1090 μg/g) (Figure 3). The termite parts were also good sources of several other elements including magnesium, manganese, copper, chromium, potassium, sodium, and zinc. Neither selenium nor molybdenum were detected in the dried termite parts. Non-physiologic or toxic metals such as aluminum, arsenic, strontium, vanadium, tungsten, and yttrium were present in the termite heads and thorax.

DISCUSSION

The termites that were the focus of this study, particularly their heads (eaten by Makiritare), contain large amounts of protein.

Overall the amino acid composition of the heads is good (Table II), compared with that of the WHO standard protein, except for the somewhat low values for the sulfur amino acids (methionine and cysteine) that are thus limiting. The chemical index of these proteins (85%) is nevertheless high and comparable with that of conventional meats.

The total fatty acid content of the samples, relative to that of the lean meats, is not high, thus indicating that termites store little lipid in the form of triacylglycerol and that most of the fatty acids in the termites is likely present in membrane phospholipids. This latter speculation is supported by the observation that approximately 80% of the fatty acids in both the heads and thorax are of the unsaturated (monounsaturated and polyunsaturated) variety. It is interesting to note that the essential fatty acids, linolenic and a-linoleic, are well represented and account for about the 90% of the unsaturated fatty acids. Furthermore, the ratio of linoleic acid to a-linolenic acid was approximately 4, which is in the range of values recommended by human nutritionists (WHO/FAO, 1995).

The termites contain considerable amounts of many elements important for human nutrition including calcium, iron, magnesium, copper, potassium, sodium and zinc. In particular, the iron

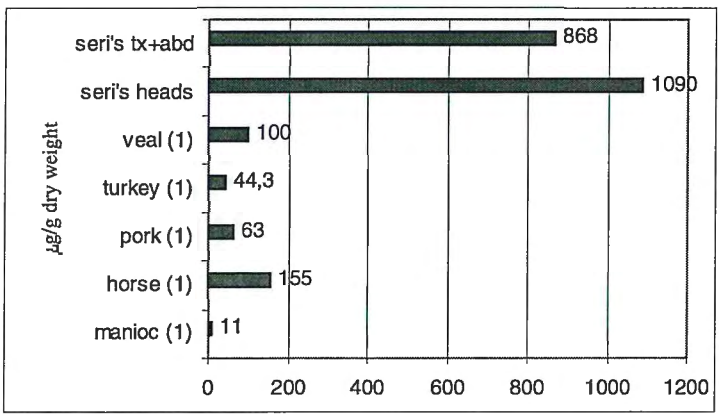

FIGURE 3 Iron content of *seri* termites and some common foods (µg/g dry weight); (1) Carnovale and Marletta, 1997.

content is very high, 10 times more than any other conventional meat (Figure 3). The Makiritare (Ye'Kuana) have a very diverse diet comprised of fish, game, fruits, and roots. The staple is, as for many other Amerindians groups, cassava (*Manihot esculenta*) which is cultivated in swiddens in the forest.

These peoples believe it very important to gather termites (*Syntermes* soldiers), earthworms (Paoletti et al. 2000, 2003), and several other insects including several caterpillars. Apparently they have no shortage of protein, but they consider such invertebrates to be a nutritionally significant food source.

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