Accepted Author's Manuscript of:

Echeverri, Juan Alvaro, and Oscar Enokakuiodo Roman-Jitdutjaño. 2011. Witoto Ash Salts from the Amazon. *Journal of Ethnopharmacology* 138 (2): 492– 502. doi:10.1016/j.jep.2011.09.047

Published version available in:

http://www.sciencedirect.com/science/article/pii/S0378874111007185

Witoto Ash Salts from the Amazon

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Abstract

Ethnopharmacological relevance: This article presents the results of an anthropological and ethnobotanical study of the vegetable salts used by the Witoto Indians of the Amazon. It thoroughly documents the species used, the processing of the salts, their chemical composition and their anthropological, nutritional and medicinal relevance.

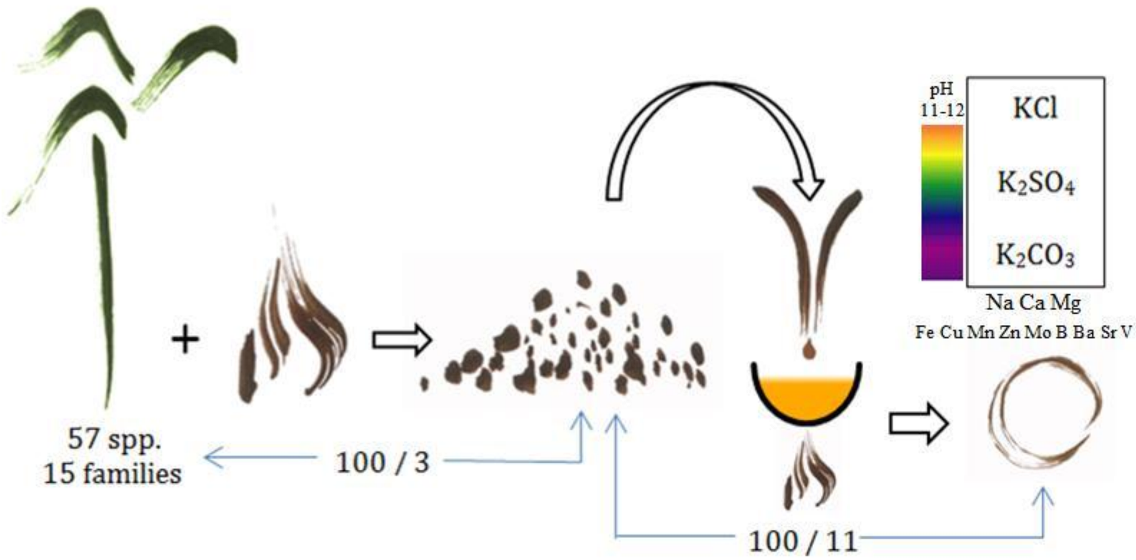
Materials and Methods: Salts from 57 plant species known to the Witoto were processed using the same materials and techniques employed by the Indians: burning plant material, lixiviating the ashes with water, and boiling down the brine to desiccate the salt. Chemical analyses of macroelements of 49 of the salts, and of microelements of 24, were conducted. Tests on the taste of the salts as perceived by the native persons were carried out.

Results: Average ratio ashes/raw material was 3.05% (from 0.71% to 10.14%); average ratio dry salt/ashes was 11% (from 1% to 37%). All the samples analyzed presented a high proportion of potassium (26.9% - 44.6%); contents of phosphorus, sodium, calcium and magnesium were less than 1%; contents of carbonate, chloride and sulfate varied greatly among the salts. Boron, molybdenum and vanadium were present in all or almost all the samples analyzed; copper, barium and strontium were also frequent; manganese, zinc and iron were less frequent.

Conclusions: There is a correlation between the concentration of the three anions and the perceived taste of the salts, the "sweet" flavor of chloride being the preferred taste. Our research shows that the culinary function of these salts is secondary to their ritual, medicinal and cosmological meaning. The search for chloride is one of the reasons to produce and consume these salts; other reasons are also important: their alkaline pH, which liberates the alkaloid of the tobacco with which the salts are mixed; and their contents of microelements, which, although not discernible in taste, are inferred from symbolic associations of the species used.

Keywords: ethnobotany, ash salts, Witoto, Northwest Amazonia

Graphical Abstract



1. Introduction

Ash or vegetable salts have been produced and consumed by many peoples from Oceania, Central Africa and America. Portères (1950, 1957) reports 158 different plant species used in Africa for the preparation of potassium lye (CO_3K_2), potash (a combination of K_2CO_3, K_2SO_4 and KOH) and culinary salts. In Africa, some species were cultivated for the preparation of ash salt: *Hydrocharis salifera* Pellegrin, *Pistia stratiotes* L., *Hygrophilla spinosa* T. Anderson (Portères, 1950: 13). Prinz (1993) suggests that it has been the abandonment of the use of vegetable salts by the Azande of Central Africa which has caused the increase in the endemism of goiter; the Azande prepare vegetable salts from the ashes of species of the Sterculiaceae, Graminae, Compositae, Marantaceae, Zingiberaceae and Loganiaceae families (Prinz, 1993: 344-345).

In New Guinea, there is a wide gradation in the sources, production, circulation and consumption of mineral, vegetable and mixed salts: from the farming and pig-raising groups of the Western highlands who produce and trade mineral salts over long distances; to the Irian Jaya, where a mixed salt is produced by soaking vegetal fibers in mineral salt springs, which are then burnt and packed in pans; and, finally, the hunter-gatherers of the lowlands who do not consume salt at all (Weller et al., 1996). But it is in the Eastern highlands of Papua New Guinea where the consumption and trade of potassium salts of vegetable origin has been widespread among the Anga-speaking groups. Of the Anga salts, the most renowned is that of the Baruya, which has served as a sort of money and is exchanged over great distances. The Baruya salt is obtained from the cultivated *Coix gigantea* and its preparation requires a sophisticated technique carried out by a specialist called a *tsaimaye* (cf. Godelier, 1969, 1986; Lemmonier, 1984). The Buang also prepare a fine salt from *Coix gigantea* with a technology similar to the Baruya (Hooley & Terit, 1972).

There are numerous reports of ash salts having been produced all over South and Central America (see Echeverri et al., 2001, for references), but chemical analyses of the salts are scarce; the few references are found in Schmeda-Hirschmann (1994), who analyzed 4 Ayoreo ash samples from the Paraguayan Chaco, and Zerries (1964), who examined the ash of a palm from the Waika of the Orinoco and reported analyses of salts conducted by Martius in the Xingú River and by Sick in British Guyana..

Despite the numerous references to the production of vegetable salts by Amerindian peoples, there are few detailed studies of their processing and chemical composition, and their anthropological relevance has been largely neglected. This article documents the ash salts produced by the Witoto Indians of Northwest Amazonia, by presenting the results of a study carried out in the Caquetá River region, Colombian Amazon, in which we extracted salt from 57 species and conducted chemical analyses of 49 of the resulting salts.

The Witoto Indians live in the Colombian and Peruvian Amazon. Their homeland stretches from the Caquetá to the Putumayo Rivers in southeastern Colombia. They number approximately 10,000 people and belong to the Witoto linguistic family, an isolated linguistic stock with three extant languages. They practice slash and burn horticulture, fishing, hunting and food-gathering. Even though they were almost exterminated during the rubber boom at the beginning of the 20th century, they have recuperated demographically and maintain their cultural and territorial autonomy.

The techniques used by the Witoto for the preparation of vegetable salt are basically the same as those documented or reported in other parts of the world. These salts are made by burning plant material from selected vegetable species, lixiviating the ashes through the use of filters, and dehydrating the resulting brine to obtain the dried salts. The Witoto use these salts primarily as an alkaline reagent to mix with tobacco paste, a thick decoction of filtered tobacco juice, which is consumed by men and women in daily life and on ritual occasions. Men consume the tobacco paste, generously admixed with ash salts, together with coca powder.

2. Background and methods

This study was conducted near the locality of Araracuara in the Caquetá River basin, Colombian Amazon, between 1996 and 2000. The two authors, an Indian elder and an anthropologist, led the research team which included a botanist, a chemist, and a number of Indian assistants. The research, done in the "Resguardo Indígena Andoque de Aduche," an indigenous reserve legally recognized by Colombian legislation, was carried out with the knowledge and authorization of its indigenous authorities. Plant collection was explicitly authorized by them, and carried out in compliance with Colombian and international regulations about research on natural resources and respect for indigenous peoples.

In four one-month field seasons we collected and processed salts from a total of 56 different plant species, plus a hive of a wild species of bee, traditionally used by the Witoto to obtain salts. We used the same materials and techniques employed by the Indians to process vegetable salt. The method basically consists of burning fresh plant material (bark, shoots, stems) over a wood fire, filtering the ashes with water, and boiling down the brine to desiccate the salt, as mentioned above.

2.1. Plant collection

We collected all the plants from the basins of the Yarí and Caquetá Rivers, in the Middle Caquetá region, located between 0° 10' and 0° 40' S, and 72° 00' and 72° 30' W. This region is formed by the intersection of sedimentary plains of Tertiary origin (dissected terraces and hills), with rocky outcrops of Paleozoic origin running to the north which create elevated plateaus, and crossed by the alluvial planes of the Caquetá River and its tributaries. The whole terrain is covered by primary rainforest, with the exception of some patches of secondary forest near Araracuara. The altitude ranges from 200 to 300 m.a.s.l. and average annual rainfall is 3,000 mm (Duivenvoorden and Lips, 1991).

The collection of vegetable material implied the destruction of the plants. In the case of arboreal species, the tree was felled with an axe and the bark extracted with the help of machetes. Only for one tree species, the giant *Couratari guianensis,* was the whole trunk burnt in-situ. In the case of palms, the shoots were mostly used, but in some cases the bark and fruits as well *(Attalea maripa),* the trunk without bark *(Bactris gasipaes)* or the whole plant *(Elaeis guinensis* – an exotic species). In the case of herbaceous species, only the stems without leaves were extracted. A few cultivated species were collected: the stems of *Ananas comosus* (pineapple), and the fruit shells of *Theobroma bicolor* and *Inga edulis.*

Some of the species are common and abundant, while others are scarce and difficult to find. The Witoto elder Enokakuiodo led the team in the field and pinpointed all the specimens. The collection of botanical samples was carried out by a botanist and an anthropologist, using standard methods. For well-known species, botanical samples were not collected but identification was corroborated in the field. For palms, we used Galeano (1991) and Henderson et al. (1995) as field guides for identification, and for trees and some herbaceous taxa, Gentry (1993).

Identification of the botanical samples was carried out by the Herbario Amazónico of the Instituto Amazónico de Investigaciones Científicas SINCHI (Bogotá, Colombia). Specimens are held at this herbarium and at the Herbario Nacional of Universidad Nacional de Colombia (Bogotá). Voucher numbers of the specimens are listed in Appendix A.

2.2. Burning of the vegetable material

The collected plant material was burnt on the ground in the open. A pyre of selected firewood was prepared. Not all combustible woods are apt for the preparation of salt. Woods that are resinous or produce too much ash are avoided. The pyre was kindled and the vegetable material was placed on top of it. The fire was monitored and from time to time the firewood and pieces of fresh plant material were moved around to ensure a homogeneous combustion. A well-prepared pyre should burn at a constant rate, without producing too much flame. The resulting ash was weighed and a sample collected.

2.3. Filtering of the ashes

When the ashes were thoroughly cool, the charcoal and other impurities were carefully separated, and the ashes were placed within a filter. We used three types of filters. The most common type, called *zekɨ* in Witoto, is a funnel-shaped structure made with strips from the stems of the palm *Iriatella setigera*, interwoven with vines. The filter is lined with leaves of a Maranthaceae and hung from a pole. A second type of filter, called *moyoɨda* in Witoto, is made with the bark of *Ochroma pyramidale,* which is folded into the shape of a funnel and tied with vines. It is supported in the same way as the *zekɨ* filter. These two types of filters can hold up to 8 kilograms of ashes. In both of them, a plug for the funnel is made, either from the stems of *Selaginella amazonica* or of cotton tow. The third type of filter is a little "hammock" made of the bark of a species of Moraceae or a piece of cloth, and tied from the tips to two supporting poles.

To filter the ashes, water was added until it began to leak from the funnel tip or the bottom of the little hammock. The lixiviated brine was collected in a recipient and water continued to be added until the filtrate became tasteless or developed a strongly alkaline flavor (like bleach). We collected samples of the filtrates, and measured their pH.

2.4. Drying of the filtrate

The collected brine was put to boil in a pot on a fire. The brine is very corrosive and requires special pots. We employed five pots: one aluminum pot covered with enamel, three fireproof glass pots of different sizes and one clay pot. The fireproof glass pots are particularly suitable for salt preparation as glass is inert and does not react with the elements of the brine. The enamel-covered pot works well so long as there are no cracks in the enamel. Formerly, drying was done over a fire in a clay pot known as a *ɨaiko.* Although the surface of those clay pots had to be finely polished to prevent the salt from penetrating and cracking them, even the best pots could only be used three or four times.

The drying of salt is a slow and tedious process. At the beginning the fire was kept hot to accelerate the evaporation. As the brine turns thicker, however, it may spurt out of the pot if the temperature is not controlled. When it begins to desiccate, the heat must be kept very low to prevent the salt from sticking to the pot. We weighed all the salts obtained and collected samples for chemical analysis.

2.5 Chemical analysis

We conducted a chemical analysis of the macroelements of 49 salts, and of the microelements of 24. Sulfate levels were determined by precipitation into barium sulfate, which was then dissolved in EDTA (ethylenediaminetetra-acetic acid) and titrated with a magnesium chloride solution. Atomic absorption (Perkin-Elmer) and a standard calibration method (Basset et al., 1979) determined the levels of potassium, sodium, calcium and magnesium. Chloride levels were determined by the Mohr titration method.

2.6. Tasting of salts

We conducted tests on the taste of the different salts, as perceived by the Witoto, to find out whether there were correlations between the perceived taste and the concentration of anions and cations, and thus determine whether the chemical contents might explain which tastes are most agreeable to the participants. We did a blind taste test of each salt with three men and two women on different dates. The answers, either in Witoto or Spanish, were recorded and arranged in a table for comparison.

3. Results and Discussion

3.1 Salt species

Appendix A lists the 57 species from which we prepared ash salts: 56 plant species from 15 botanical families, plus one species of insects. Palms (Arecaceae) are the most common source of ash salts, with 23 species plus 3 varieties. The other botanical families, in decreasing numerical order, are: Cyclanthaceae (6 spp.), Lecythidaceae (5 spp.), Sapotaceae (5 spp.), Bombacaceae (2 spp.), Mimosaceae (2 spp.), Olacaceae (2 spp.), and one species each of Araceae, Bromeliaceae, Dichapetalaceae, Euphorbiaceae, Rutaceae, Sterculiaceae, Strelitziaceae and Thurniaceae. Of the Arecaceae family, the most common genus is *Astrocaryum*, with 5 species, followed by *Geonoma* (3 spp., 6 varieties), *Attalea* (3 spp.), *Bactris* (3 spp.), *Mauritia* (2 spp.), *Oenocarpus* (2 spp.), and, with one species each, *Elaeis*, *Iriartea*, *Lepidocaryum*, *Mauritiella*, and *Pholidostachys.* The only non-vegetable ash salt is obtained from burning the beehive of *Trigona truculenta* (Apidae).

This is a *nearly* exhaustive list of the species used by the Witoto to process salt. Seven other species were named by Enokakuiodo, but we did not collect and process them:

Bactris riparia Mart. (Arecaceae). Witoto *jimaikɨrɨ.*
Bactris simplicifrons Mart. (Arecaceae). W. *joda jimena.*
Cyathea sp. (Cyatheaceae). W. *yaragɨ*.
Ischnosiphon leucophaeus (Poepp. & Endl.) Körn. (Maranthaceae). W. *uizaikonorɨ.*
Oenocarpus bacaba Mart. (Arecaceae). W. *izɨna*
Zea mays L. (Poaceae). W. *beyarɨ* (cultivated)
Indet. tree sp. (cf. Phyllanthaceae). W. *jaɨeniraɨ*.

These would add three more species to the set of palms, and at least four new botanical families to the list in Appendix A. Schultes and Raffauf (1990), in their comprehensive inventory of medicinal plants of Northwest Amazon, list 8 species used by the Witoto to extract salt, 7 of which coincide with our list.

The indigenous criteria for the selection of this particular set of species derive from the Myth of Creation of the Cosmos. As narrated by Elder Enokakuiodo, during the process of creation, the Father Creator Moo Buinaima suffered all kinds of illnesses and troubles; he searched for them in his body and cast them away, into what was going to become the world. Later on, after the world of the beginnings was turned upside down, each of those powerful and polluted substances of the Creator was to become the source of a set of entities of this, the world we live in today. Each of the species used to extract salt derives from the body of the Father Creator, and is thus linked to that myth and to a set of other species, entities and objects (mammals, insects, other plants, spirits, tools) by its morphological characteristics and particularly its Witoto name, which commemorates those primordial events. The body of the Creator turned into botanical species is thus conceived of as an image of our own human body. The morphology and biology of these plants manifest processes in our own bodies which would otherwise remain invisible.

That palms are so prominent in this list is a proof of the economic, cultural and symbolic importance of this botanical family for many Amazonian peoples; and it is worth noting the mythological significance of the most common palm genus, *Astrocaryum,* whose dense armor of thorns are symbols of the hardships suffered by the Creator.

3.2. Salt processing data

From these species we collected a total of 9,945.3 k of fresh plant material. On average, each collecting expedition yielded 90 kilos of vegetable material, ranging from 7 to 490 kilos. We processed salt a total of 106 times, in some cases, processing the same species several times or experimenting with a mixture of species.

Burning times, measured from the kindling of the pyre to the moment when all the material was fully consumed, varied in accordance with the type and quantity of material. The shortest burning time was 1hour and 15 minutes (12 kilograms of bark from a species of Rutaceae) and the longest 10 hours (170 kilograms of the *Trigona turculenta* beehive). We used dry wood from at least 13 botanical families of trees, the most common of the Lecythidaceae and Sapotaceae families.

The average ratio of ash-to-raw material weight was 3.05%, ranging from 0.71% (burning 196 k of pieces of the trunk of *Mauritia carana)* to 10.14% (59 k of stems of *Cyclanthus bipartitus).*

The color of the filtrate varied from a pale (almost transparent) yellow to a reddish orange; the most common color was yellow, in different intensities. The orange-red color might have been due to the passage of charcoal through the filter.

We measured the pH of the filtrate, which ranged from 8 to 14 (basic to strongly basic), 11 and 12 being the most frequent values.

It took an average of 1 hour and 25 minutes (in a range of 0:49 to 4:03) to dry one liter of brine. The average concentration of the brine put to dry was 66 g/l (in a range of 12 to 255 g/l). The average ratio between the weight of the dry salt and the weight of the filtered ash was 11%, in a range from 1% to 37%.

3.3 Chemical composition of the salts

Ash salts are characterized by a low concentration of sodium and a high concentration of potassium ions. We conducted chemical analyses of the macroelements of 49 of the 57 species listed in Appendix A (those whose numbers are prefixed with an asterisk). Results of the chemical analyses for carbonate, chloride, sulfate, potassium, phosphorus, sodium, calcium and magnesium are shown in Appendix B. All the samples analyzed presented a high proportion of potassium (26.9% - 44.6%), whereas the contents of phosphorus, sodium, calcium and magnesium reached a maximum of 0.48%, 0.39%, 0.62% and 0.31% respectively. This may be explained by the fact that salts with low solubility (e.g. calcium sulfate) are retained in the ashes. By contrast, the contents of carbonate, chloride and sulfate varied greatly among the salts: carbonate ranged from 0.38% to 34.07%, chloride from 1.10% to 26.16% and sulfate from 3.24% to 55.90%.

Results of the analyses of the microelements in the 24 samples of salts are shown in Appendix C. Boron, molybdenum and vanadium are present in all or almost all of the samples analyzed. Copper, barium and strontium are also frequent. Manganese, zinc and iron are less frequent. These minor elements play important metabolic roles in the human organism, and are required in minimum concentrations. Below we discuss the importance of microelements in relation to the symbolic associations of the salt species.

In six cases we analyzed several salts extracted from the same species. Even though the contents of the macroelements vary widely within the same species, certain factors indicate the need to be cautious about drawing conclusions:

We extracted four salts from different parts of two specimens of the *Attalea maripa* palm: we extracted the bark and the flowers from one, and the fruits and the bark plus the young shoot from the other. The salts from the flowers and fruits showed higher percentages of carbonate, while those extracted from the bark were richer in chloride.

The three salts from *Cyclanthus bipartitus* were actually from three varieties of the same species, regarded as separate plants in the taxonomy of the Witoto. One, called *jogaɨrɨ*, grows in swampy areas to a maximum height of 2 m; the second, called *jibuirɨ*, is a smaller, riparian plant that reaches a maximum of 1 m; and the third, *gorongorɨ*, is a bigger plant which grows on *terra firme* (dry, inter-fluvial land) and may reach 4 m. The taller, dry-land variety shows higher percentages of carbonate, whereas chloride is higher in the two waterside varieties

The three salts from the *Gustavia hexapetala* tree were prepared from two specimens: one mature tree, from which the bark was taken, and a younger one, from which we extracted the bark and also used the wood of the trunk separately.

In the case of the epiphyte *Ludovica* sp., the two salts were obtained from two separate batches collected from two different sites. Remarkably, the composition of one of the resulting salts is strikingly different from the other.

Finally, for the *Matisia* af. *intricata* tree, two analyses were made of the same salt extracted from a single specimen The first analysis, made immediately after the sample was processed, showed a considerably higher content of carbonate than that found in the second analysis of another sample of the same salt made a few weeks later, after the excess bleach was allowed to lixiviate.

The only thing we can predict about the chemical composition of an ash salt, according to our observations, is that it will have a high concentration of potassium (30-50%); the anion composition is quite unpredictable (even among individuals of the same species), and all have a variable array of microelements in low concentrations. Thus, we can say that Witoto salts are mostly a combination of potassium chloride, potassium sulfate and potassium carbonate, together with other compounds in low concentrations. Next, we discuss the role of the main anions in the perceived taste of the salts.

3.4. Anions and salt taste

The most frequent terms used by the five native persons to describe the taste of the salts were: strong, biting, hot, tasty, sweet, cool and insipid. These set of terms can be organized around three sets of oppositions:

cool / hot
sweet / strong, biting
tasty / insipid

These three sets define the two extremes of the taste of a salt: at one, the salts are perceived as hot, strong (or biting) and insipid, which are the least desirable tastes; at the other, the salts are perceived as cool, sweet and tasty, the most palatable tastes. The third set may combine with the other two: a salt can be hot but tasty, or sweet but insipid. Some tasters described how the perception changed on the tongue: "hot, but then it cools down," or provided nuanced descriptions: "Cool, somewhat biting and good taste." Some salts were perceived by all very consistently, either as "sweet and cool" or as "hot and biting", other salts prompted shifting and differing responses. A summary description of the tastes was worked out for each salt in terms of the three sets of oppositions, and compared with the chemical composition of the salts. Anion composition proved to be meaningfully correlated with taste perceptions, as shown below.

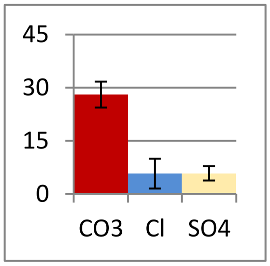
Table 1 presents a summary of the descriptions of the taste of 49 salts, together with their anion composition. The list is arranged in five groups, established by a cluster analysis using the data of anion concentration as variables. We gave each group a label which summarizes the overall perception of the flavor of the salts of the group, and illustrate each group with a graph displaying the average concentration of the anions and their standard deviation (population).

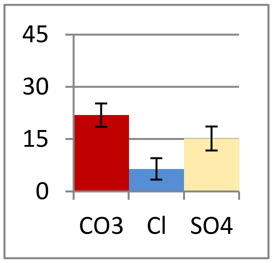
Table 1

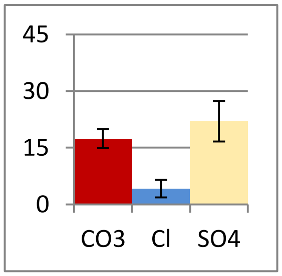
Groups of salts according to anion concentration correlated with taste perception

(Figures in **boldface** show average concentration for the group. Graphs illustrate average anion concentration and standard deviation for each group)

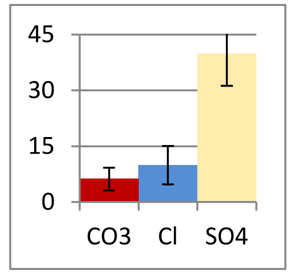
Species	CO_3	Cl	SO_4	Taste
	28.0	**5.8**	**5,8**	**VERY STRONG**
Matisia af. *intricata*	28.8	2.8	5,0	Very strong
Eriotheca cf. *macrophylla*	27.3	2.3	8,4	Very strong
Phenakospermum guyannense	27.4	3.3	8,0	Strong but good
cf. *Dulacia* sp.	34.1	13.5	3,2	Strong, hot, biting
Sphaeradenia sp.2	22.6	7.0	4,4	Insipid, strong, hot
	21.9	**6.5**	**15,2**	**STRONG**
Hyeronyma alchorneoides	29.4	2.3	12,8	Strong
Parkia pendula	24.0	5.6	11,6	Insipid
Oenocarpus mapora	23.5	4.8	13,9	Insipid and biting
cf. *Ludovica* sp.	24.6	1.4	17,9	Hot but good taste
Attalea maripa	20.5	6.5	11,4	Hot, strong, somewhat sweet
Mauritiella armata	21.3	6.3	17,2	Strong, tasty
Attalea maripa	18.3	9.2	13,3	Somewhat strong
Cyclanthus bipartitus	18.7	6.5	19,4	Somewhat hot
Mauritia flexuosa	19.8	10.1	12,3	Sweet and cool
Gustavia hexapetala	18.6	11.8	21,8	Sweet
	17.4	**4.1**	**22,0**	**HOT**
Chrysophyllum sanguinolentum	16.9	3.6	15,9	Strong
Asplundia sarmentosa	22.9	9.6	16,0	Hot, strong
Gustavia hexapetala	19.2	5.0	18,1	Somewhat biting
Ecclinusa bullata	18.0	2.8	19,6	Hot, somewhat strong
cf. *Chaunochiton loranthoides*	15.1	1.1	25,3	Insipid
Tapura cf. *guianensis*	15.6	3.2	23,7	Hot, insipid
Ecclinusa ulei	17.2	3.2	32,6	Strong, insipid
Manilkara bidentata	14.4	4.5	24,8	Hot, strong

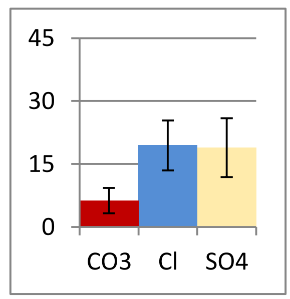






	6.2	**9.9**	**39,9**	**SWEET AND BITING**
Bactris fissifrons	8.9	2.2	39,5	Sweet and hot
Geonoma maxima	8.2	4.5	34,7	Sweet
cf. *Ludovica* sp.	10.0	6.8	39,3	Sweet, hot
Manilkara bidentata	8.8	6.7	34,6	Biting and then sweet
Astrocaryum chambira	4.8	2.2	44,1	Sweet
Oenocarpus bataua	10.9	9.7	30,5	Cool and tasty
Matisia af. *intricata*	6.0	6.1	37,2	Cool
Astrocaryum murumuru	4.6	7.6	53,1	Somewhat biting and cool
Gustavia longifolia	2.5	7.3	49,6	Sweet somewhat biting
Gustavia hexapetala	9.0	15.3	55,9	Sweet
Sphaeradenia sp.1	9.4	14.1	26,4	Sweet and a little strong
Astrocaryum gynacanthum	7.3	13.5	34,8	Cool, sweet
Astrocaryum sciophilum	2.5	11.8	44,0	Sweet
Bactris humilis	4.8	10.6	23,2	Sweet, cool
Geonoma macrostachys	2.2	13.2	42,2	Sweet
Couratari guianensis	0.4	14.4	48,4	Sweet
Cyclanthus bipartitus	4.9	22.5	40,0	Cool and insipid
	6.3	**19.4**	**18,9**	**SWEET AND COOL**
Lepidocaryum tenue	10.5	8.5	21,8	Sweet and a little strong
Astrocaryum jauari	8.3	10.5	22,0	Somewhat strong, hot
Lecythis pisonis	7.2	17.4	21,3	Sweet
Attalea maripa	10.2	24.2	10,4	Cool and sweet
Attalea maripa	6.5	21.1	7,9	Sweet
Attalea racemosa	5.4	20.3	19,9	Cool and sweet
Geonoma maxima	4.3	20.6	33,3	Cool, sweet
Cyclanthus bipartitus	3.2	26.2	18,5	Cool
Thurnia sphaerocephala	0.9	26.1	14,9	Cool and sweet





. The dominant anions in the salts analyzed are chloride, carbonate and sulfate, in varying proportions. Table 1 shows that there is a correlation between the concentrations of these three anions and the perceived taste of the salts. Salts with a high concentration of chloride are perceived as "sweet and cool," whereas salts with a high concentration of carbonate are perceived as "strong and hot." The presence of sulfate combines with the sensation produced by the other two anions: it may moderate the strong flavor of carbonates into "biting," blunt the sweet flavor of chloride into "insipid," or produce mixed perceptions.

The "Very Strong" group presents the highest concentration of carbonate in combination with low concentrations of chloride and sulfate; the five salts in this group are all perceived by the natives as strong, biting and hot. The ten salts of the "Strong" group also present a high concentration of carbonate, with rising concentrations of chloride and sulfate; most of these salts are perceived as strong or hot, but this description is qualified ("somewhat strong," "strong but good taste") and two salts are described as sweet. The eight salts of the "Hot" group show rising concentrations of sulfate, decreasing concentrations of carbonate and low concentrations of chloride; half of the salts are perceived as hot and the others either as strong, somewhat biting or insipid. The fourth group, “Sweet and Biting” – the largest, with 17 salts – has the highest concentrations of sulfate, together with low concentrations of carbonate and chloride; all the salts in this group are generally perceived as sweet, in several cases with the qualification “somewhat biting” or “tasty.” Finally, the “Sweet and Cool” group shows a predominance of chloride, with sulfate slightly lower and the lowest concentration of carbonate; 7 of the 9 salts are described as sweet and cool, and only 2 as somewhat strong.

There does not seem to be a correlation between these groups and the botanical families from which the salts were extracted. Tree species tend to produce hot and strong salts, richer in carbonate.

The Witoto prefer salts which are “sweet” *(naɨmerede)*, which means both sweet and salty. As these salts have very low contents of sodium, the perception of saltiness is rather correlated with the presence of chloride, as is clear from Table 1. “Coolness,” on the other hand, is correlated with a low concentration of carbonate. Sulfate seems to influence the perception of sweetness, weakening the strong flavor of carbonate, but also rendering the salt insipid when chloride is low. The groups Very Strong (5 salts) and Strong (10) are carbonate salts, the group Hot (8) are carbonate-sulfate salts, the group Sweet and Biting (17) are sulfate salts and the group Sweet and Cool (9) are chloride salts. The latter two groups, which include over half of the samples, contain salts whose flavor is palatable for the natives; salts of the other groups are too hot or strong but still apt to be used.

Thus, the Witoto prefer salts with a good concentration of chloride (at least 20%), together with sulfate (no more than 20%), and tolerate up to 10% of carbonate. For comparison, we extracted salt from a species of Lecythidaceae, not recognized by the Witoto as a salt species. The salt from the bark of this tree (indet.) yielded 50.2% carbonate, 3.4% chloride and 41% sulfate, by far the highest concentration of carbonate.

3.5. The paradox of ash salt as a substitute for sodium chloride

In Table 2, we present data on the chemical composition of ash salts from Africa, New Guinea and other regions of America, as reported in the literature. We have omitted available analyses of ashes from the table, but we summarize them in a paragraph after it. Sections A and B of Table 2 are taken from Portères’ (1950) catalogue of African salt plants; section A lists salts whose composition is expressed in terms of the percentages of oxidized elements, and section B lists salts whose composition is expressed in terms of the compounds of chloride, carbonate and sulfate. Section C shows the data on two salts from the New World reported by Zerries (1964), and section D presents data collected by Lemmonier (1984) from several ethnic groups of Papua New Guinea.

Table 2
Chemical composition of ash salts from other parts of the World

A. Africa (elements)

	Place	*Species*	*Cl*	*Na_2O*	*K_2O*	*SO_3*	*CO_2*	*P_2O_5*	*CaO*	*MgO*
1	Chad	*Salvadora persica* L.	54.80	11.08	29.20	3.69			0.41	0.37
2	Chad	*Salvadora persica* L.	43.31	10.16	47.00	0.83				
3	Cameroon	*Echinochloa crus-galli* (L.) P. Beauv.	42.81	1.63	56.73	5.24			1.19	0.55
4	Lisala	[aquatic grasses]	33.58	0.28	41.10	11.00	9.20		0.24	0.10
5	Belgian Congo	[mixture]	20.40	3.08	33.56	19.58	16.74	0.16	0.28	0.24
6	Belgian Congo (Ntaga)	*Pluchea dioscoridis* (L.) DC.	19.25	8.61	25.15	39.25				
7	Oubangui (Bunda)	*Imperata cylindrica* (L.) Raeusch.	14.26	10.64	45.40	16.21		5.48	2.27	4.78
8	Africa	*Murdannia nudiflora* (L.)Brenan [*Commelina nudiflora* L.]	6.70	3.80	56.00	9.40				
9	Africa	*Murdannia nudiflora* (L.)Brenan [*Commelina nudiflora* L.]	5.90	3.08	77.00	3.08				
10	Rhodesia	*Helianthus annuus* L.		2.30	49.60			1.50		
11	Africa	*Pennisetum* spp.							0.24	0.14

Source: Portères, 1950: 32, 47-48, 50, 54, 59-60.

B. Africa (compounds)

	Place	*Species*	*NaCl*	*KCl*	*K_2SO_4*	*K_3CO_2*
12	Chad	*Salvadora persica* L.	67.60	28.76		
13	Oubangui (Manja)	[mixture]	42.10	16.80	33.10	6.30
14	Kasai-Lukemie basins	[mixture]	39.56	46.80	9.94	
15	Africa	*Pennisetum* spp.	36.5			
16	Chad	*Salvadora persica* L.	26.83	57.88		
17	Chad	*Salvadora persica* L.	19.17	66.36		
18	Chad	*Salvadora persica* L.	9.62	81.16		
19	Africa	*Cyrtosperma senegalense* (Schott) Engl. + *Halopegia azurea* K. Schum.	0.85	45.30	27.50	16.30
20	Kasai-Lukemie basins	[mixture]		43.33	35.34	
21	Chari Valley (Ngapou)	[mixture]		53.96	36.87	7.35
22	Kasai-Lukemie basins	[mixture]		63.46	32.12	
23	Kemo River (Tokbo)	[mixture]		64.26	29.28	4.26

	Place	*Species*	*NaCl*	*KCl*	K_2SO_4	K_3CO_2
24	Kasai-Lukemie basins	[mixture]		67.12	27.12	
25	High Ubangui (Bonjo)	[aquatic plants]		67.38	28.73	1.17
26	Kasai-Lukemie basins	[mixture]		74.23	21.76	
27	Gabon (Jekri)	*Pistia* sp.		75.00	22.60	
28	Africa	*Cyperus haspan* L.		77.80	18.50	

Source: Portères, 1950: 28, 31, 47, 55-56, 60.

C. America

	Place	*Species*	*NaCl*	*KCl*	K_2SO_4	K_3CO_2
29	British Guyana	*Mourera* sp.	50.40	33.60		
30	Brazil (Xingú)	*Eichhornia* sp.	0.00	86.70		

Sources: Martius, in Zerries (1964: 82) and in Portères (1957: 157), for British Guyana; Sick, in Zerries, 1964: 82, for Brazil (Xingú).

D. Papua New Guinea

	Ethnic groups	*Species*	*Na*	*CL*	*K*	SO_4	CO_3	*Ca*	*Mg*
31	Baruya	*Coix gigantea* J. König	+	46.00	~40	5.00	n.d.	+	+
32	Kokwaye	Indet.	2.00	46.00	46.00				0.03
33	Kokwaye	Indet.		41.50				traces	
34	Watchakes	Indet.	2.90	39.50	49.10				0.10
35	Baruya	*Coix gigantea* J. König		36.20			?	0.05	
36	Watchakes	Indet.		36.10				traces	
37	Menye	*Coix* spp.		29.00	44.30	16.00			
38	Menye	*Coix* spp.	0.40	22.10	38.10	13.70	1.50	2.40	0.03
39	Putei	Indet.	0.01	11.60	~50	3.30	39.60	0.20	0.15
40	Fore	Indet.	3.00	11.60	57.30	0.65	0.24	0.30	2.00
41	Tauri	Indet.		7.40	31.30	46.00	11.50		
42	Langimar	Indet.		4.10				0.08	
43	Langimar	Indet.	7.90	3.70	42.60				0.20
44	Putei	Indet.	0.09	3.60	~50	46.70	10.40	0.06	0.02
45	Komako	*Cyathea* sp.	0.06	1.00	~50	0.60	49.20	0.06	0.03
46	Komako	*Cyathea* sp.	0.13	0.60	~50	4.70	48.40	0.25	0.25
47	Mumeng	Indet.	0.11		45.50				

Source: Lemmonier, 1984: 106-108.
Abbreviations: ~ approximate; + present; n.d.: no data; indet.: indeterminate.

In some parts of the world, ashes, rather than salts, are preferred for consumption. The Gidra-speaking Papuans of the Oriomo Plateau, lowland Papua New Guinea, consume the ashes of the tree species *Melaleuca leucadendron* and *Acacia mangium*. Ashes from *Melaleuca leucadendron* present calcium content as high as 34.9% and those from *Acacia mangium* a magnesium content as high as 15.7%, and the latter also contain a rather high concentration of sodium (10.4%) (Ohtsuka et al., 1987). Croft and Leach (1985) reported a 17.8% calcium content in the ashes of the *Asplenium nidus* fern used as a source of salt in the inland areas of Papua New

Guinea. Freund et al. (1965) report a 20.1% concentration of sodium in ashes from *Eriocaulon australe*, and Schmeda-Hirschmann (1994) reports a 2.27% concentration of sodium found in the ashes from the *Maytenus vitis-idaea* traditionally used by the Ayoreo, an Amerindian group of the Paraguayan Chaco; Schmeda-Hirschmann suggests that taste preferences may account for the ash being consumed.

The ash salts reported by Portères throughout Central Africa were used for culinary purposes, supposedly as a substitute for sodium chloride. Portères (1950: 12, our translation) provides a definition of these culinary salts, which applies very well to the case of the salts we examined from the Witoto:

> The good ash salts are especially rich in KCl (rarely do they contain some NaCl) with a more or less important percentage of K_2SO_4 and very little or nothing at all of K_2CO_3. … Very often the salt contains a lot of K_2CO_3. Certain salt substitutes do not have chloride but are only formed by potassium sulfate and carbonate.

It is remarkable that most of these salts have a very low content of sodium and that a good number of them have low contents of chloride. This leads Portères to express his "perplexity" (1950: 15) about the physiological value that one might attribute to these salts in view of the absence or minimal presence of NaCl, the high percentages of KCl, the high rate of $K_2CO_{3,}$ and the constant presence of K_2SO_4 in all of them.

Nevertheless, Portères' characterization in the quotation above best describes the New Guinea and Witoto salts rather than the African samples, as listed in Table 2 (A, B). It is noteworthy that 11 of the 28 salts of African origin show a high percentage of sodium (far above the contents we found in Witoto salts) or sodium chloride (percentages as high as 67.6 in salt no.12, *Salvadora persica*). The other African salts listed are indeed compounds of potassium chloride and potassium sulfate in varying proportions. Portères does not provide complete data on the contents of potassium carbonate, but it might be high where contents of chloride and sulfate are low.

New Guinea salts show a chemical profile more like that of the Witoto salts. Salts 31-38 in Table 2 have a high content of chloride (above 20% and up to 46%) and low contents of sulfate, a profile that generally corresponds to our Sweet and Cool group, and shows even "sweeter" salts, considering that the highest concentration of chloride in the Witoto salts is only 26.2%.The Baruya salt (no. 31, *Coix gigantea*), which is mostly potassium chloride, is one of the most highly valued in Papua New Guinea. This might indicate that it is the desired chemical profile for an ash salt, as in the case of the Witoto. Salts 39-47, on the other hand, are comparable to salts from our groups Sweet and Biting to Very Strong. Some of these salts must be very unpalatable.

The culinary function of New Guinea ash salt is secondary to its ritual uses, mainly in initiation ceremonies, and to its role in inter-tribal exchanges, as it is clearly shown by Godelier (1969, 1986) and Lemmonier (1984). Portères' perplexity derives from the idea that ash salt is a substitute for sodium chloride. It is generally agreed that agricultural societies need to consume sodium chloride because the vegetables they eat do not provide them with an adequate intake of sodium, but, on the contrary, contain an excess of potassium (cf. Denton, 1984). That these agricultural societies produce a potassium salt as a replacement for sodium chloride is a paradox; and that many of these salts are potassium sulfate and carbonate rather chloride – which gives the sensation of saltiness – is even more puzzling.

3.6. Ash salts for the Witoto

The Witoto, and other neighboring groups which also extract vegetable salts, are agricultural peoples, but they are also hunters and fishers and relish a daily intake of animal protein (even though it may be scarce at some times). Besides, for at least two generations they have learnt to consume sodium chloride in the form of store-bought salt, which is now part of their eating habits. We can confidently state that they are not depleted of sodium; nevertheless the production and consumption of ash salts is maintained to date.

For the Witoto, ash salts are not substitutes for sodium chloride neither are they used primarily for culinary purposes. Their elders tell us that, formerly, small amounts of salt from *Astrocaryum gynacanthum* Mart. were added to their food, but no other salts were used for this purpose. Nowadays, the consumption of ash salts in large amounts and even the consumption of certain kind of salts for children or pregnant women is deemed hazardous.

Ash salt has an important ritual significance for the Witoto. In the ceremonies, ash salt compacted as a brick is given in payment for wild game or for highly valued ritual services. These salts are used primarily as an alkaline reagent for alkaloids, mainly the tobacco paste (a thick paste resulting from the prolonged decoction of tobacco juice), which is mixed with generous amounts of ash salt. The ash salt provides an alkaline medium which makes the tobacco alkaloids soluble in water, and the salty ("sweet") and slightly biting flavor of the salt stimulates salivation. The licking of tobacco paste is an everyday practice of every adult man and the production of ash salt is carried out not only by ritual specialists but also by ordinary men, who do it every time they need a supply of salt to mix with their tobacco. Many men state that for them certain kind of species yield better and larger amounts of salt than others, and in the ceremonies, the skill needed to prepare good salt (sweet and white) is highly rewarded.

Not all salts are considered equal. There are "public salts" that can be used in ceremonies and safely consumed by children, women and foreigners, and "study salts," which are those prepared by men who are in the process of learning specialized knowledge. In fact, the preparation of multiple kinds of salts is part of the training of a young man. The preparation and consumption of small amounts of every kind of salt is said to be like a “vaccine” which trains the body and mind in the use of the diverse and potentially harmful minerals contained in the vast array of salt sources, which are conceived of as substances derived from the body of the Creator. Most of the salts we analyzed are study salts. In our experience, the species used to extract salt for everyday use and which may be given to the participants in public ceremonies are from a reduced number of species. The most common species are the palms *Astrocaryum gynacanthum* and *Attalea maripa*, and the riparian species *Spathiphyllum* sp. and *Sphaeradenia* sp. All of these are public salts, safe for consumption by anyone. In general, palms and riparian species are deemed good and safe salts, whereas salts from tree species are considered more hazardous. One exception for palms is *Astrocaryum chambira* Burret, which is said to be a “poison” for pregnant or menstruating women and for dogs. Not all the neighboring tribes extract salt from tree barks; the Andoque group, for instance, only extracts salt from palms and from riparian plants. For the preparation of the special salt brick used in the ceremonies as ritual payment a large number of species must be used, which gives it a high value as it is said to represent “the whole world.”

Salt has a double meaning for the Witoto. On the one hand, it represents “all the evils in this world,” and in ritual discourse it is given metaphorical names corresponding to harmful animals and elements of the forest (snakes, sting ants, spiders, scorpions, thorns and so forth); on the other hand, salt is said to be “milk from the mother’s breast,” as it is purified by the process of burning and filtering (see Echeverri, 2000, and Echeverri et al., 2001, for a detailed explanation). As we explained above, plant species of the forest are said to originate from the body and humors of the Father Creator, and are associated with insects, animals and human illnesses, which all share that common primordial origin, signaled by their Witoto names. These names and associations might be clues for the medicinal potential of these salts, as each one contains the vestiges of primordial illnesses.

The available data is not conclusive in demonstrating a relation between the meaning the Witoto ascribe to each species and the mineral contents of its salt, although we present four examples that provide some clues in this direction.

One remarkable example is that of *Bactris humilis*, known in Witoto as *iñoyɨ*, which means “woman-plant” (and is also associated with the anteater). The salt from this species yielded the highest content of zinc, 500 ppm, which is known to be an element required for pregnant and lactating women (cf. Merialdi et al. 1999), and is important in the production of insulin, which the fetus requires from the 4thmonth of gestation onwards; it also has the highest concentration of sodium, which is crucial for liquid retention and the formation of amniotic liquid. (We thank an anonymous reviewer of the *JEP* for some of the above information.)

Parkia pendula is a huge tree associated with the power of the terrestrial animals which are said to have "crushed" the body of Father Creator. The salt from this species yielded by far the highest contents of molybdenum (700 ppm); some studies (cf. Moss 1999) have shown that molybdenum has an important function in relieving aches and muscular pains.

Attalea maripa is a palm which yields one of the most commonly used salts. This salt is associated with a transformative purification, and traces a parallel between the Father Creator´s cleansing of his body during his learning process and the menstrual flow of women. The association of this species with blood is noteworthy, since its salt is the only one with an iron content.

Finally, a species of *Sphaeradenia* is said to represent of madness of the Father Creator, a symbolic association which perhaps derives from the fact that this salt has the highest number of microelements detected (7 out of 8) and the highest total concentration of microelements (2280 ppm).

4. Conclusions

Most plants are rich in potassium and poor in sodium. Portères (1950) wondered about the reasons for the production and consumption of vegetable salts, which he called "alimentary salts". He discussed Bunge´s theory that societies with a vegetarian regime sought in salt the sodium necessary to balance a potassium-rich diet. It may hold true for mineral salt, but Portères' study of the chemical composition of ash salts, confirmed by the data presented here, shows that they are generally rich in potassium chloride and very poor in sodium chloride. He then discussed the theory of Lapique, who claimed that these salts were sought for their bitter taste, rejecting it on the grounds that many plants may also provide a bitter taste. His own theory was then that the scarcity of carbonates in the salts he analyzed pointed to chloride as the element sought in ash salts.

The ash salts produced by the Witoto mainly consist of compounds of potassium chloride, potassium carbonate and potassium sulfate. Roughly half of the samples analyzed present a high content of potassium carbonate (above 15%) and only 40% of the samples have a chloride content of more than 10%. The Indians strongly favor the "sweet" taste of the salts, which correlates with their chloride content, and judge unpalatable the "strong" taste, which is an index of carbonate, as shown above. The taste tests would thus tend to confirm Portères' theory, but the selection of species, which in many cases yielded carbonate salts, would indicate that the Witoto nevertheless consider some unpalatable salts to be desirable.

We thus allege that the Witoto not only seek chloride in their ash salts, but that at least two other chemical features are significant in their choice of salt sources: their pH and their contents of microelements..

All the ash salts we studied are basic to strongly basic. Ash salts are mostly employed by the Witoto and other neighboring groups as an alkaline reagent to liberate the alkaloids of tobacco and other alkaloid-rich plants (such as a species of *Virola*, a hallucinogenic species also mixed with ash salt). Carbonate and sulfate produce alkaloid compounds. When the tobacco paste, which is acid (pH ~5), is mixed with an ash salt rich in carbonate, the mixture generates carbon dioxide, causing the tobacco paste to inflate, which is judged by Indians as an indication of an appropriate salt. Thus, while the role of the chloride content is to produce the desired taste, it would seem that the Witoto appreciate the alkaline pH of the carbonate and sulfate compounds and employ it to activate the alkaloids of plants, especially tobacco, which they combine with these salts.

The main cation in all the salts analyzed is potassium, with a concentration ranging from nearly 30% to nearly 50%. The content of sodium, calcium and magnesium is less than 1%, and all the salts contain traces of a variable set of microelements. The Witoto diet is rich in potassium, and they warn that the consumption of large amounts of these salts may be harmful. Even small amounts of the other elements, particularly the microelements, have strong metabolic effects and may be the source of the medicinal uses of these salts or their potential harm. Although the presence of these elements is not detectable by taste, our research suggests that the symbolic associations of plants derived from the Myth of Creation may represent a cultural codification of the benefits or dangers of these elements which guides the Witoto´s use of ash salts. That is, the associations of the plants with illnesses, entities and states of the soul signal the potential healing or toxic power of the resulting salts in terms of microelements, rather than the concentration of the major anions.

Thus, “public salts” would be those that combine two properties: on the one hand, their anions composition renders them palatable, and on the other, their symbolic associations indicate a composition of microelements which makes them safe. In the case of *Astrocaryum chambira*, for example, its association with the power of thunder indicates that even though its salt may be “sweet” it is not suitable as a public salt.

The chemical composition of the Witoto salts is quite similar to that of the salts reported in studies of indigenous societies in Papua New Guinea. For the latter groups as for the Witoto, the chief uses of the salts are ritual and medicinal, rather than culinary, unlike African salts, which are substitutes for sodium chloride, according to the literature. The ash salts employed by the Witoto are not a substitute for mineral salt and despite their adoption of sodium chloride in recent decades, they continue to produce and consume them. Our research shows that the culinary function of these salts is secondary to their ritual and cosmological significance. The plant species and technical procedures the Witoto employ to make salt are governed by metaphors which convey lessons about the fundamental processes of life embodied in its mineral essence, and especially its double meaning of harmful forces and vital nourishment. Those harmful forces mirror the illnesses of the psyche, society and the natural world, and the elaboration and consumption of salt is regarded as a “study” which enables the apprentice to attain a corporeal knowledge of the mineral essence of the wide variety of plant species identified as sources of salt.

Acknowledgements

This study counted on the financial support of the COAMA Program for the Consolidation of the Amazon, led by The Gaia Foundation (UK); the Earth Love Fund (UK); the Instituto Colombiano de Cultura COLCULTURA (Colombia); and the Insituto Amazónico de Investigaciones IMANI of Universidad Nacional de Colombia, Amazonia Campus. We would like to thank the biologists Olga L. Montenegro and Dairon Cárdenas, curator of the Herbario Amazónico of the Instituto SINCHI (Colombia), for the identification of the botanical samples; the chemist Andrés López for the chemical analyses of the salts; Doris Monroy for the illustration of the graphical abstract; and Jimmy Weiskopf, for revising the English text.

We would also like to thank the anonymous reviewers of the *Journal of Ethnopharmacology* for their comments and criticism, which helped to improve the manuscript. We dedicate this article as a memorial to Simón Román (1963-2008), Enokakuiodo's son, who participated in this study from its start.

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Appendix A

List of species

	Species	Voucher numbers SAL(m)-	Witoto names	Parts collected
1	*Ananas comosus* (L.) Merr. (Bromeliaceae)	[nc]	*ofaiyɨ*	stems
*2	*Asplundia sarmentosa* Galeano & R. Bernal (Cyclanthaceae)	9	*turao*	stems
*3	*Astrocaryum chambira* Burret (Arecaceae)	[nc]	*ñekɨna*	shoots
*4	*Astrocaryum gynacanthum* Mart. (Arecaceae)	21	*ruirɨyɨ*	shoots
*5	*Astrocaryum jauari* Mart. (Arecaceae)	[nc]	*korɨna*	shoots
*6	*Astrocaryum murumuru* Mart. (Arecaceae)	23	*kɨkɨyɨ*	shoots
*7	*Astrocaryum sciophilum* (Miq.) Pulle (Arecaceae)	38	*júúikuruyɨ*	shoots
8	*Attalea insignis* (Mart. ex H. Wendl.) Drude (Arecaceae)	60	*barɨkaɨ*	shoots
*9	*Attalea maripa* (Aubl.) Mart. (Arecaceae)	[nc]	*jarɨna*	shoots, bark, fruits
*10	*Attalea racemosa* Spruce (Arecaceae)	16	*uiyoyɨ*	shoots
*11	*Bactris fissifrons* Mart. (Arecaceae)	54	*zitorɨ*	stems
12	*Bactris gasipaes* Kunth (Arecaceae)	[nc]	*jimena*	trunk without bark
*13	*Bactris humilis* (Wallace) Burret (Arecaceae)	14	*iñorɨ*	shoots
*14	cf. *Chaunochiton loranthoides* Benth. (Olacaceae)	[nc]	*vɨɨrɨgɨ*	bark
*15	*Chrysophyllum sanguinolentum* subsp. *balata* (Ducke) T.D. Penn. (Sapotaceae)	44	*bafákona*	bark
*16	*Couratari guianensis* Aubl. (Lecythidaceae)	24	*jafegɨ, jafena*	wood of the trunk
17	cf. *Cyclanthus* sp. (Cyclanthaceae)	66	*emairɨ*	all plant
*18	*Cyclanthus bipartitus* Poit. ex A. Rich. (Cyclanthaceae)	10, 17, 22	*jogaɨrɨ, gorongorɨ, jibuirɨ*	all plant
*19	cf. *Dulacia* sp. (Olacaceae)	2	*chapena*	bark
*20	*Ecclinusa bullata* T.D. Pennington (Sapotaceae)	40	*ɨáikona jífikona*	bark
*21	*Ecclinusa ulei* (Krause) Gilly ex Cronquist (Sapotaceae)	39	*daɨro*	bark
22	*Elaeis guineensis* Jacq. (Arecaceae)	[nc]	[exotic species]	stems
*23	*Eriotheca* cf. *macrophylla* (K. Schum.) A. Robyns (Bombacaceae)	41	*jáikɨna*	bark
24	cf. *Eschweilera* sp. (Lecythidaceae)	65	*jɨákona*	bark
*25	*Geonoma macrostachys* var. *acaulis* (Mart.) Skov (Arecaceae)	35	*zíínuikorɨ*	shoots
*26	*Geonoma macrostachys* var. *poiteauana* (Kunth) A.J. Hend. (Arecaceae)	37	*zíínuikorɨ*	shoots

	Species	Voucher numbers SAL(m)-	Witoto names	Parts collected
*27	*Geonoma maxima* var. *chelidonura* (Spruce) Henderson (Arecaceae)	58	*fɨkaɨngo ererɨ*	shoots
*28	*Geonoma maxima* var. *maxima* (Poit.) Kunth (Arecaceae)	31	*goguirɨ*	stems
*29	*Geonoma maxima* var. *spixiana* (Mart.) Henderson (Arecaceae)	29, 32, 34	*goguirɨ*	stems
*30	*Geonoma stricta* var. *piscicauda* (Dammer) Henderson (Arecaceae)	33	*goguirɨ*	stems
*31	*Gustavia hexapetala* (Aubl.) Sm. (Lecythidaceae)	1	*jameda miñɨkona*	bark
*32	*Gustavia longifolia* Poepp. ex O. Berg (Lecythidaceae)	28	*jameda ɨme ñukura*	bark
*33	*Hyeronyma alchorneoides* Allemão (Euphorbiaceae)	57	*ekoroai*	bark
34	Indet. (Rutaceae)	46	*jeedo ɨaiña*	bark
35	*Inga edulis* Mart. (Mimosaceae)	[nc]	*jizaiko*	fruit
36	*Iriartea deltoidea* Ruiz & Pav. (Arecaceae)	[nc]	*jɨáɨgɨna, fegona*	trunk without bark
*37	*Lecythis pisonis* Cambess. (Lecythidaceae)	5	*ɨairo jero*	bark
*38	*Lepidocaryum tenue* Mart. (Arecaceae)	18	*ererɨ*	shoots
*39	cf. *Ludovica* sp. (Cyclanthaceae)	26	*emoyaɨ*	stems
*40	*Manilkara bidentata* (A. DC.) A. Chev. (Sapotaceae)	53	*meníñokɨaɨ jɨfaiño*	bark
*41	*Manilkara bidentata* subsp. *bidentata* (Sapotaceae)	46	*meníñokɨaɨ*	bark
*42	*Matisia* af. *intricata* (A. DC.) A. Chev. (Bombacaceae)	43	*ɨáigɨna mɨzégɨna*	bark
43	*Mauritia carana* Wallace (Arecaceae)	62	*kañakona, duizékɨna*	trunk
*44	*Mauritia flexuosa* L. f. (Arecaceae)	[nc]	*kɨnena*	shoots
*45	*Mauritiella armata* (Mart.) Burret (Arecaceae)	27	*zííyaña, yumuna*	shoots
*46	*Oenocarpus bataua* Mart. (Arecaceae)	48	*komaña*	shoots, fruits
*47	*Oenocarpus mapora* H. Karst. (Arecaceae)	20	*gurɨkaɨ*	shoots
*48	*Parkia pendula* (Willd.) Benth. ex Walp. (Mimosaceae)	19	*rangogɨ, jífibegɨ*	bark
*49	*Phenakospermum guyannense* (L.C. Richard) Endler ex Miq. (Strelitziaceae)	55	*iyoberɨ, uiyoberɨ*	shoots
50	*Pholidostachys synanthera* (Mart.) H.E. Moore (Arecaceae)	64	*fekorɨ*	shoots
51	cf. *Spathiphyllum* sp. (Araceae)	61	*jirúrurɨ*	shoots
*52	*Sphaeradenia* sp.1 (Cyclanthaceae)	11	*nonókoo*	stems
*53	*Sphaeradenia* sp.2 (Cyclanthaceae)	26	*eirɨ*	stems

	Species	Voucher numbers SAL(m)-	Witoto names	Parts collected
*54	*Tapura* cf. *guianensis* Aubl. (Dichapetalaceae)	42	*zeema ɨaiña*	leaves and branches
55	*Theobroma bicolor* Bonpl. (Sterculiaceae)	[nc]	*mɨzeko*	fruits
*56	*Thurnia sphaerocephala* (Rudge) Hook f. (Thurniaceae)	13	*zaɨkorɨ*	stems
57	*Trigona truculenta* Almeida (Apidae)	SAL(z)-01	*emokɨ*	beehive

*Species with chemical analyses.
[nc]: Not collected

Appendix B

Chemical Analyses of Macroelements

Species	CO_3^{--} %	Cl^- %	SO_4^{--} %	P- (ppm)	K^+ %	Na^+ (ppm)	Ca^+ (ppm)	Mg^{++} (ppm)
Asplundia sarmentosa	22.91	9.59	16.00	210	41.59	1,090		
Astrocaryum chambira	4.81	2.20	44.10		33.80	1,366	127	911
Astrocaryum gynacanthum	7.30	13.52	34.80	1,000	38.48	270	330	
Astrocaryum jauari	8.33	10.46	22.00	3,700	36.09	300		
Astrocaryum murumuru	4.56	7.63	53.10	240	42.80	473	505	36
Astrocaryum sciophilum	2.46	11.79	43.97	680	35.90	267	2,399	2,281
Attalea maripa (bark&shoots)	10.24	24.20	10.40		48.50	192	424	70
Attalea maripa (fruits)	20.49	6.50	11.40		30.40	241	330	226
Attalea maripa (bark)	6.51	21.13	7.87	2,700	41.04	650		
Attalea maripa (flowers)	18.34	9.21	13.29	900	34.20	1,140		
Attalea racemosa	5.36	20.27	19.90	160	31.70	397	2,478	2,734
Bactris fissifrons	8.88	2.20	39.50		42.60	380	1,133	893
Bactris humilis	4.81	10.57	23.20	400	37.74	3,910		
cf. *Chaunochiton loranthoides*	15.06	1.10	25.30		28.20	1,899	1,899	254
Chrysophyllum sanguinolentum	16.92	3.62	15.87	270	41.30	640		
Couratari guianensis	0.38	14.39	48.40		37.87	200		
Cyclanthus bipartitus (var.1)	3.16	26.16	18.50	50	31.40	2,348	2,246	2,960
Cyclanthus bipartitus (var.2)	18.69	6.54	19.40	900	29.40	549	1,142	39
Cyclanthus bipartitus (var.3)	4.90	22.46	40.00	410	41.52	120	460	10
cf. *Dulacia* sp.	34.07	13.50	3.24	200	37.70	560		
Ecclinusa bullata	17.96	2.81	19.62	150	36.06	120		
Ecclinusa ulei	17.23	3.23	32.63	600	34.20	290	1,494	61
Eriotheca cf. *macrophylla*	27.30	2.33	8.39	50	39.12	210		
Geonoma macrostachys	2.25	13.22	42.16	620	41.29	530		
Geonoma maxima	8.21	4.50	34.70		33.50	1,022	1,429	312
Geonoma máxima + G. stricta	4.31	20.55	33.34	250				
Gustavia hexapetala (mature tree bark)	9.01	15.26	55.90	70	28.90	476	1,382	18
Gustavia hexapetala (wood)	19.19	4.98	18.07	400	27.00	299	2,271	3,119
Gustavia hexapetala (young tree bark)	18.56	11.83	21.80	280	38.79	70	2,094	2,649
Gustavia longifolia	2.52	7.25	49.61	90	34.53	530		
Hyeronyma alchorneoides	29.38	2.30	12.80		37.80	194	1,368	38
Lecythis pisonis	7.17	17.44	21.30	100	39.18	130		
Lepidocaryum tenue	10.49	8.50	21.80	360	32.70	599	1,854	2,420
cf. *Ludovica* sp. (site 1)	9.96	6.82	39.25	520	29.30	2,949	2,085	2,270
cf. *Ludovica* sp. (site 2)	24.60	1.40	17.90		40.70	627	2,133	2,115
Manilkara bidentata (var.1)	14.43	4.45	24.84	570	39.06	680		
Manilkara bidentata (var.2)	8.77	6.72	34.63	520	35.00	310		

Species	CO_3^{--} %	Cl^- %	SO_4^{--} %	P- (ppm)	K^+ %	Na^+ (ppm)	Ca^+ (ppm)	Mg^{++} (ppm)
Matisia af. *intricata* (new salt)	28.81	2.75	5.01	200	30.00	115	1,451	77
Matisia af. *intricata* (salt after 1 mo.)	5.96	6.05	37.21	470				
Mauritia flexuosa	19.80	10.10	12.30		36.70	496	1,201	517
Mauritiella armata	21.34	6.31	17.15	2,770	30.40	196	1,147	116
Oenocarpus bataua	10.92	9.70	30.50		35.20	77	393	111
Oenocarpus mapora	23.49	4.80	13.90	4,800	33.10	534	553	177
Parkia pendula	24.00	5.60	11.56	400	38.51	1,040		
Phenakospermum guyannense	27.36	3.30	8.00		33.40	247	942	21
Sphaeradenia sp.1	9.44	14.09	26.40	50	39.12	460		
Sphaeradenia sp.2	22.64	6.95	4.36	600	37.23	620		
Tapura cf. *guianensis*	15.62	3.15	23.71	50	38.60	576	6,262	1,563
Thurnia sphaerocephala	0.91	26.12	14.87	300	44.64	360		

Appendix C

Chemical Analyses of Microelements

Species	Fe (ppm)	Cu (ppm)	Mn (ppm)	Zn (ppm)	Mo (ppm)	B (ppm)	Ba (ppm)	Sr (ppm)	V (ppm)
Asplundia sarmentosa		10			7	10			50
Astrocaryum gynacanthum		10			5	30			50
Astrocaryum jauari		10			7	50			50
Attalea maripa (bark)	20			3	20	150	300	200	200
Attalea maripa (flowers)		20	100		20	100	300	100	100
Bactris humilis			20	500	20	70	500	100	500
Chrysophyllum sanguinolentum		10			5	30			70
Couratari guianensis		10			5	30			20
Cyclanthus bipartitus (var.3)		10			15	50	20		100
cf. *Dulacia* sp.				3	20	150	300	200	200
Ecclinusa bullata		10			5	50	20		70
Eriotheca cf. *macrophylla*		10			5	50	20		20
Geonoma macrostachys		10			30	30	20		150
Geonoma maxima		10			15	20			30
Gustavia hexapetala (wood)		10	50		15	150	1,000	100	50
Gustavia longifolia						10			20
Lecythis pisonis		10			5	50	20		50
Manilkara bidentata (var.1)		10			5	30	20		100
Manilkara bidentata (var.2)		10			5	20			70
Matisia af. intricata					15	700	200	100	150
Parkia pendula		10	20		700	500	100	100	200
Sphaeradenia sp.1		10	100	200	20	1,500	100	200	150
Sphaeradenia sp.2		50			15	200			200
Thurnia sphaerocephala			50	3	50	70	200	300	700