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## Morphometric patterns and preferential uses of *Capsicum* peppers in the State of Roraima, Brazilian Amazonia

Reinaldo I Barbosa<sup>1</sup>; Moisés Mourão Júnior<sup>2</sup>; Francisco Joaci de F Luz<sup>3</sup>

<sup>1</sup>INPA-Núcleo de Pesquisas de Roraima, R. Coronel Pinto 315, Centro, 69301-150 Boa Vista-RR; <sup>2</sup>Embrapa Amazônia Oriental, C. Postal 48, 66095-100 Belém-PA; <sup>3</sup>Embrapa Roraima, C. Postal 133, 69301-970 Boa Vista-RR; reinaldo@inpa.gov.br; mmourao@cpatu.embrapa.br; chefia@cpafrr.embrapa.br

### ABSTRACT

Our objective was to study distinctions in the morphology of the pepper fruits (*Capsicum* spp., Solanaceae) used by indigenous (living in traditional villages) and non-indigenous groups (originated from migration and colonization, with or without miscegenation, living on non-indigenous lands) in the State of Roraima, Northern Brazilian Amazonia. In this sense, we used a database with 182 subsamples of *Capsicum* spp. Accessions were collected at 39 sites (14 indigenous and 25 non-indigenous), which were characterized additionally in relation to the predominant phytophysiognomy (savanna or forest) and home zone (rural or urban). We found morphological differences in pepper fruits related to both phytophysiognomy and home zone of the collecting site, but not to ethnical origin. We believe those differences are more related to the inherent crop practices, which suffer strong environmental influence, than to user preference. Both indigenous and non-indigenous groups preferred morphotypes from *C. chinense* and *C. frutescens*, which have small and highly pungent fruits. Nevertheless, fruit color was not important. These morphotypes are used by both indigenous and non-indigenous users for preparing sauce and *jiquitaia* (pepper powder). We suggested 'cultural adherence' as the reason for the common preferred use of peppers by both ethnical groups analyzed in Roraima.

**Keywords:** *Capsicum chinense*, *Capsicum frutescens*, agrobiodiversity, ethnic botanic, pungency, descriptors.

### RESUMO

#### Padrões morfométricos e usos preferenciais de pimentas *Capsicum* spp. em Roraima, Amazônia brasileira

O objetivo deste estudo foi verificar distinções no padrão morfológico de frutos de pimentas do gênero *Capsicum* spp. (Solanaceae) utilizados por grupos tradicionais indígenas (vivendo em aldeias) e não-indígenas (derivado da migração/colonização, contendo ou não miscigenação, situados fora de áreas indígenas), em Roraima, norte da Amazônia brasileira. Para tanto foi utilizado um banco de dados com 182 subamostras de *Capsicum* spp. coletadas em 39 localidades daquele estado (14 indígenas e 25 não-indígenas). As localidades foram caracterizadas também por tipos fitofisionômicos predominantes (savana ou floresta) e por zona domiciliar do usuário (rural ou urbana). Os resultados indicaram haver diferenças morfológicas nos frutos de pimenta relacionadas tanto a fitofisionomia, quanto a zona domiciliar da área de coleta, mas não a origem étnica do grupo. Isto indica que as diferenças estão relacionadas mais a fatores inerentes aos tratos culturais, fortemente influenciados pelo ambiente, que à preferência do usuário. Os morfotipos com frutos de menor peso e alta pungência das espécies *C. chinense* e *C. frutescens*, independente da cor, foram os preferidos dos usuários indígenas e não-indígenas para produção de molhos e *jiquitaia* (pó de pimenta). A 'aderência cultural' é sugerida para explicar o uso preferencial comum de pimentas entre os agrupamentos étnicos analisados em Roraima.

**Palavras-chave:** *Capsicum chinense*, *Capsicum frutescens*, agrobiodiversidade, etnobotânica, pungência, descritores.

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The peppers from the genus *Capsicum* spp. (Solanaceae) are native from the Americas. Archaeological records indicate that *Capsicum* species were already consumed at least 8,600-5,600 BC in the Andean regions of Peru and 6,500-5,500 BC in Mexico (Nuez *et al.*, 1998), which makes *Capsicum* one of the first domesticated species used for food in the Americas (Pickersgill, 1969). The earlier descriptions of the use and shape of *Capsicum* fruits were made by the chroniclers of the Christopher Columbus' first voyages to the Americas (Pietro Martire d'Anghiera, in 1493, and Diego Alvarez Chanca, in 1494).

Both reported the existence of a spicy fruit that was used as condiment by the inhabitants in La Española, now the Dominican Republic and Haiti (Lembeck, 1987). In Brazil, the first reports are attributed to Hans Staden, a German shipwrecked who settled along the coast with the *Tupinambá* indigenous group, between 1,547-1,555 (Reifschneider, 2000).

Due to its broad use in cookery and medicine, *Capsicum* species were very rapidly disseminated to other parts of the world (Mateos *et al.*, 2003). From the sixteenth century downwards, Spanish and Portuguese

started bringing *Capsicum* to their colonies in Africa and Asia through its commercial corridors (Andrews, 1993). The exchange and dissemination of genetic material suggests that, at first, the settlers carried the standard fruit selection (color, pungency, shape and size) and propagated the use as they found in America to spread the genus. Routes covering different human groups and distinct *Capsicum* dispersal centers in the Americas were used for the transit and exchange of food resources (cultural diffusion) much faster and more intensively than in the pre-Columbian period (Heiser, 1965).

However, this does not mean that the standards were maintained over time, also because *Capsicum* species exhibit a wide variety of shapes, colors and sizes (Walsh & Hoot, 2001).

Preference patterns indicate cultural traits (food, medicinal, ritual, etc.), which are intrinsic to different population groups. These preferences provide information on market acceptance and the processing industry in distinct regions and groups. Preferences appear as consequence of the cultural independence that encourages ideas and practices, which, in their turn, coupled with local environmental specificities, benefit certain types of plants (Portis *et al.*, 2006). Studies that support the advance of knowledge on *in situ* and *ex situ* strategies to preserve genetic resources provide a basis for the development of regional agricultural programs and land use plans (Tewksbury *et al.*, 1999; Guzman *et al.*, 2005).

This study aimed to determine morphometric distinctions between the patterns of *Capsicum* spp. fruits used by traditional indigenous populations and non-indigenous groups (migrant/settlers). We took the State of Roraima, situated on the Northern edge of the Brazilian Amazonia as case study. We also wanted to check the existence of association between preferred uses and biometric standards, color and pungency of fruits for each of the *Capsicum* species and morphotypes investigated.

## MATERIAL AND METHODS

**Database** - We used the database (DB) of *Capsicum* pepper species and cultivars consumed in the State of Roraima (Barbosa *et al.*, 2002, Barbosa *et al.*, 2006) to search for distinctions in the pattern of fruit choices and uses between indigenous (IN) and non-indigenous (NI) groups. The DB was generated between 2000 and 2001 and contains information on 182 accessions (subsamples), collected at 39 sites in Roraima, 14 classified as indigenous and 25 as non-indigenous. In both cases, we added information on phytophysiology (savanna or forest) and home area (urban or rural). In the current study, we took the 163 (89.6%) subsamples

that had information on all fields needed for the assembly of the matrix analysis. The variables selected for analysis were: (1) species (taxonomic classification and domestication status): (i) DOME (domesticated, 4 species), (ii) SEMI (semidomesticated, 1) and (iii) WILD (wild, 1); (2) morphotype: the 163 accessions were clustered into 86 morphotypes, regardless of the collecting site and the common name provided by the user; (3) predominant color: (Y) yellow (including shades of cream and orange) and (R) red (including variations); (4) pungency: structured in four classes based on the SHU scale (Scoville Heat Unit) as (L) low (<25,000 SHU), (M) medium (25,000 – 75,000 SHU), (H) high (75,000 – 150,000 SHU) and (VH) very high (>150,000 SHU); (5) fruit shape: modified from IPGRI (1995), (i) elongated, (ii) block, (iii) belly, (iv) cone, (v) oval, (vi) round and (vii) variable; (6) preferential use: based on the information received upon collecting the material, as (i) sauce (either creamy or liquid), (ii) sauce and *jiquitaia* (pepper powder), (iii) sauce and salad (fruits consumed *in natura*), (iv) ornamental (not used as food), (v) salad and steamed (used for cooking) and (vi) other uses (rare, for example, in rites); (7) fruit fresh weight, in grams (g), based on the average of ten mature fruits randomly collected or given by the user, classified into (IPGRI, 1995): (i) <4.5 g, (ii) 4.6 - 9.0 g, (iii) 9.1 - 13.5 g, (iv) 13.6 - 18.0 g (v) 18.1 - 22.5 g, (vi) 22.6 - 27.0 g, (vii) 27.1 - 31.5 g and (viii) >31.6 g; (8) fruit width and length, in centimeters (cm), following the IPGRI guidelines (1995). Morphological markers 7 and 8 were used for statistical analysis. For the morphometric characterization, we used 10 fruits per morphotype collected at random or given by the user.

**Data Analysis** - The DB was regrouped according to color, pungency, shape, preferential use and weight of fruits, generating a code for each user (sampling unit). We then carried out a descriptive analysis based on ethnical groups (IN and NI), phytophysiology (forest or savanna) and home zone (rural or urban). We used the cluster dissimilarity analysis (D2-*Mahalanobis*) with the subsequent application of a

probabilistic criterion to understand the existence of homogeneous groups (Johnson & Wichern, 1998). This multivariate technique takes into account the distance between groups formed by a set of sub-samples (multivariate samples), based on the correlations between the morphological markers (variables) that were considered for analysis. In this study we used fruit width (cm), length (cm), weight (g) and shape index (average length:width = L:W). The test of Scheffé was adopted to provide a statistical distinction among the media for these markers (Manly, 1994). In addition to the grouping, we carried out a factorial sorting (Factor Analysis) in order to understand how each component (axis) influenced the variation among groups and which morphological characteristics have stronger discriminating power. Finally, all morphometric characteristics were grouped by species, morphotype, color, shape, pungency and use of fruits to allow studying the preferential distinctions between indigenous and non-indigenous groups.

## RESULTS AND DISCUSSION

**Species biometric standards** - Over 70% of the analyzed subsamples were *Capsicum chinense* Jacq. (Table 1). Bell pepper (*C. annuum* L. var. *annuum*) fruits had the highest average weight and dimensions (length and width), while *C. annuum* L. var. *glabriusculum* (semi-domesticated) and *C. frutescens* L. had the lowest values. *C. baccatum* var. *pendulum* (Willd.) Eshbaugh and *C. annuum* L. biometric standards for fruit weight and length differed significantly from the others at the 5% probability (Scheffé test). These results agreed with the taxonomic characteristics described for the main *Capsicum* cultivated species (Pickersgill & Heiser, 1969) and therefore are consonant with the expected morphometric separation (Smith & Heiser, 1957). The statistical differences in the morphometric patterns herein identified are merely expressing the history of the *Capsicum* domestication process, which was guided by the characteristics that were privileged by a given human group

**Table 1.** Biometric quantification of fruits of different species and varieties of *Capsicum* (Solanaceae) peppers derived from the database of the State of Roraima, Brazil (quantificação biométrica dos frutos das diferentes espécies e variedades de pimentas *Capsicum* (Solanaceae) provenientes do banco de dados do estado de Roraima). Boa Vista, INPA, 2007.

Specie <sup>1</sup>	N <sup>2</sup>	Weight (g)	Length (cm)	Width (cm)
<i>C. annuum</i> (except bell pepper)	4	11.10 a	5.31 a	2.44 a
<i>C. annuum</i> var. <i>annuum</i> (bell pepper)	6	30.10 b	8.17 b	4.42 b
<i>C. annuum</i> var. <i>glabriusculum</i>	9	0.34 c	1.11 c	0.71 c
<i>C. baccatum</i> var. <i>pendulum</i>	9	12.21 a	5.11 a	3.60 d
<i>C. chinense</i>	117	3.47 d	3.62 d	1.63 e
<i>C. frutescens</i>	18	0.30 e	1.70 e	0.48 f

<sup>1</sup>Values preceded of same letter in the vertical do not differ significantly using level of 5% according to the test of Scheffé (valores precedidos de mesma letra na vertical não diferem significativamente no nível de 5% segundo o teste de Scheffé).

<sup>2</sup>Number of accessions (subsamples) analyzed.

**Table 2.** Average and standard deviation of the morphologic markers, ordered according to the test of Scheffé (média e desvio padrão dos marcadores morfológicos, ordenados segundo o teste de Scheffé). Boa Vista, INPA, 2007.

Groups	Morphological markers <sup>1</sup>			
	Width (cm)	Length (cm)	Weight (g)	L:W
G <sub>1</sub>	2.17±0.29ab	3.33±0.76ab	3.90±1.30ab	1.55±0.40b
G <sub>2</sub>	1.32±0.96b	3.03±2.04b	3.38±6.32b	2.48±1.44a
G <sub>3</sub>	1.63±1.12b	3.45±2.33ab	3.87±5.43b	2.43±1.47a
G <sub>4</sub>	2.09±1.46a	4.33±3.16a	7.60±9.48a	2.39±1.45a
Total	1.68±1.19	3.56±2.49	4.60±6.80	2.42±1.44

<sup>1</sup>Values preceded of same letter in the vertical do not differ significantly using level of 1% according to the test of Scheffé (valores precedidos de mesma letra na vertical não diferem significativamente no nível de 1% segundo o teste de Scheffé).

and seem to be independent of having taken place at centers of dispersal or elsewhere.

**Grouping users** - The application of the distance of *Mahalanobis* for developing a dendrogram based on the association between fruit morphological characteristics and ethnic group (indigenous and non-indigenous), phytophysiology (forest or savanna) and home zone (rural or urban) generated four distinct user groups (Figure 1).

The first group (G1) includes three subsamples collected with indigenous people who live in the forest, in rural areas. Compared to the others, this is the most homogeneous and isolated group. The indigenous group who cultivate these subsamples, although in contact with other people, preserved the preferential morphometric characteristics of the fruits they traditionally grow. Some studies report the use of *C. frutescens*

among the Waimiri-Atroari (Milliken *et al.*, 1992) and the Yanomami (Milliken & Albert, 1997) ethnic groups for medical purposes (ophthalmia) and on cookery. *C. frutescens* is one of the most widespread *Capsicum* species and was considered by Smith & Heiser (1957) as widely used throughout the Amazonia.

The second group (G2) assembles 32 subsamples cultivated by indigenous (IN) and non-indigenous (NI) residents in rural areas of the savanna. The ethnic groups (IN and NI) included in G2 have been in intense interaction since the beginning of colonization/migration in Roraima. It was in savanna areas that the first and closest miscegenation contacts took place. Therefore, it is expected that usages and habits were exchanged between these two groups. Schomburgk (1840) attested the historical common use of peppers by locals and travelers transiting throughout these savanna

sites.

The third group (G3) comprises 92 subsamples cultivated by non-indigenous from both rural and urban areas, living in the savanna. This group forms what Winklerprins (2002) called the 'rural-urban continuum'. The city serves as a reference of housing, an extra income source and a place with better health and education opportunities. For this group, Berg & Silva (1988) had already detected *Capsicum* morphotypes in homes and markets in Boa Vista, the State capital, with the varied uses. Nevertheless, these authors did not care about species or how they were employed in cookery or for medical purposes.

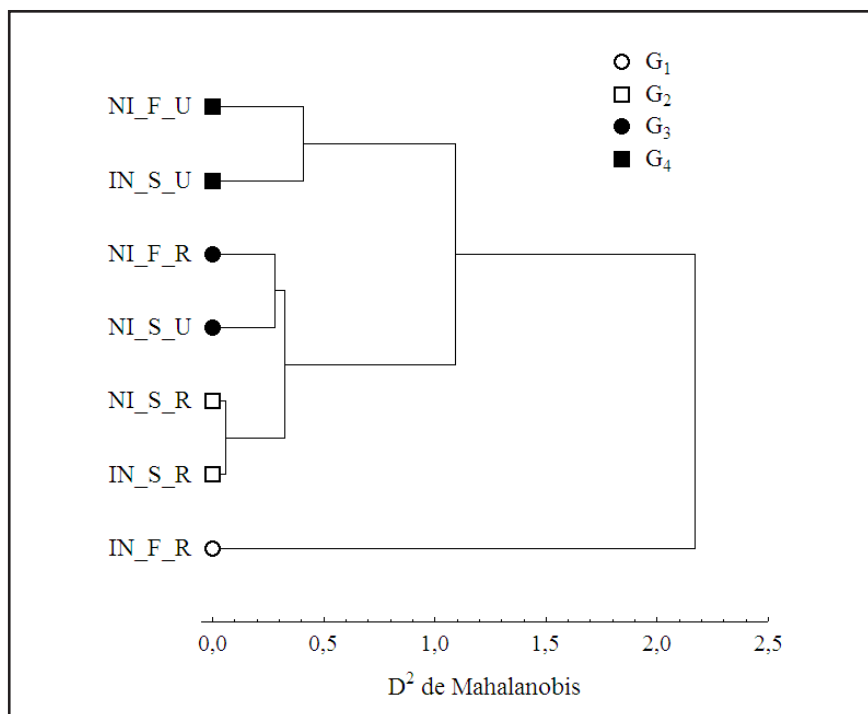
The fourth group (G4) gathered 36 subsamples cultivated by (a) non-indigenous living in small towns and cities (urban) throughout the Southern section of road BR-174 (forest), in general, migrants from the North-Northeast of the country; and (b) indigenous living in urban areas of the savanna. The last form is a movement "indigenous village-city" that confers to indigenous people broader access to paid work and health facilities. This is the most conflicting group of subsamples, which apparently demonstrates that *Capsicum* species and cultivars have a wider transit than what is represented by Roraima's geographic borders. These genetic resources exchange and dissemination movements are broad and mix cultural traits from different Brazilian regions in Roraima (more strongly in the post-1970).

The short distance between G2, G3 and G4, the best sampled groups, with 160 subsamples (Figure 1), can indicate that these three groups form a more compact cluster, far apart from G1 (indigenous villages located in forest regions). The latter has a smaller number of observations (3) and lays far apart from the other groups, representing geographic areas which are more isolated from urban centers. A larger number of samples from these sites should produce more refined information about the use of *Capsicum* by these ethnic groups, regardless of the contacts between them and other human groups which may have introduced



**Table 3.** Eigenvalues and eigenvectors of the morphological markers evidenced by factor analysis; values in boldface:  $|\lambda| \geq 0.60$  (autovalores e autovetores dos marcadores morfológicos evidenciados pela análise fatorial; valores em negrito:  $|\lambda| \geq 0,60$ ). Boa Vista, INPA, 2007.

Eigenvectors from morphological markers	PCA I	PCA II
Width (W)	-0.89	-0.40
Length (L)	-0.81	0.54
Weight	-0.94	-0.18
LW: Ratio	-0.08	0.98
Eigenvalue	2.33	1.44
% of variance explained	58.37	35.99
Cumulative % explained	58.37	94.36



**Figure 1.** Dendrogram of dissimilarity among consumer groups of peppers *Capsicum* spp. (NI= non-indigenous and IN= indigenous; F= forest and S= savanna; U= urban and R= rural) (dendrograma de dissimilaridade entre os grupos consumidores de pimentas *Capsicum* spp. (NI= não-indígena e IN= indígenas; F= floresta e S= savana, U= urbano e R= rural)). Boa Vista, INPA, 2007.

recent habits and usages.

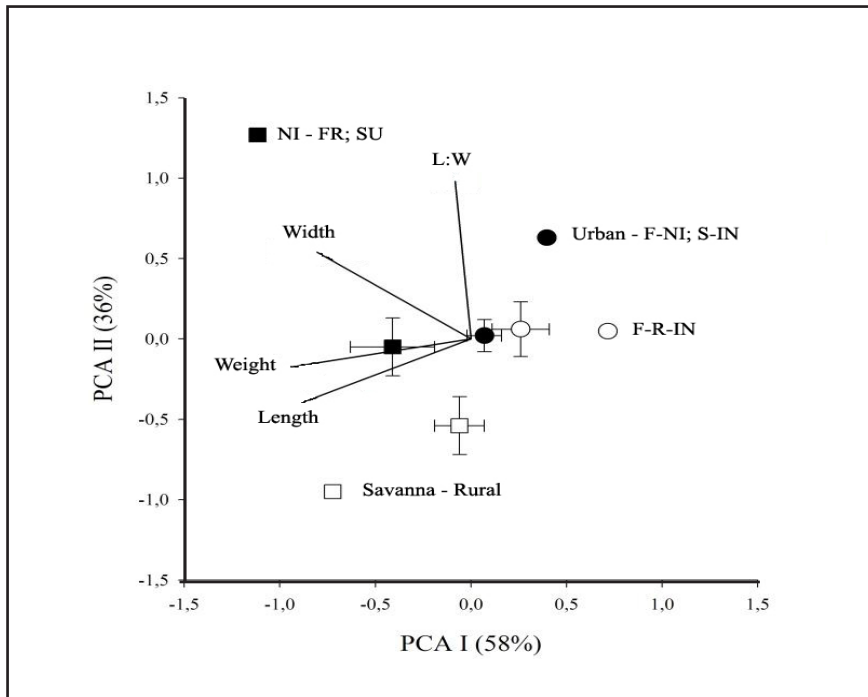
**Morphological markers as determinants of ethnic groups** - The clustering of the *Capsicum* samples allowed for the calculation of the mean and standard deviations for the morphological markers in each class (Table 2). The largest absolute distances between G1 and the other groups were recorded for fruit length:width ratio (L:W), confirmed as statistically significant by Scheffé's test. The PCA I (58% of the total variability) revealed significant differences between the eigenvectors for fruit length, width and

weight, all with negative orientation (Table 3, Figure 2). In PCA II (36% of the total variability), only the L:W eigenvector was significant, with positive orientation. Morphological markers were used in the past to determine inherited characteristics that could be used to discriminate *Capsicum* species and cultivars. Although morphological markers are no longer being frequently adopted for this type of study due to the use of molecular markers (Costa *et al.*, 2006; Portis *et al.*, 2006), in our current study they were sensitive enough to discriminate ethnic groups

and determine their constitution. Sudré *et al.* (2006) using 13 multivariate variables described by IPGRI (1995), not involving fruit weight and size, identified differences among subsamples of the evaluated species. The two PCA axes explained almost all the variability observed among the *Capsicum* accessions we used, suggesting that morphometric markers are effective for identifying preference distinctions from *Capsicum* consumers.

**Grouping of species / morphotypes by preferred use** - The most representative *Capsicum* spp. morphotype in the ethnic groups, both indigenous and non-indigenous, was *Murupi* (*C. chinensis*). *Murupi* fruits are elongated, range from red to yellow, have high pungency and weigh less than 4.5 g each. Non-indigenous preferably use it as sauce, while indigenous associate sauce with *jiquitaia* (pepper powder). Morphotypes with fruits of smallest weight, length and width were those identified as highly pungent, therefore used to prepare sauce and *jiquitaia* (pepper powder). This was a suggestion made by Cochran (1940), indicating that genotypes with smaller fruits carry also high pungency heritability factors. These are characteristics of *C. chinense* and *C. frutescens*, which are used by both indigenous and non-indigenous. The two species have wide cultural diffusion in both ethnic groups and are geographically present in the commercial routes since the first contacts (Smith & Heiser, 1957; Heiser, 1969).

Fruit size and pungency are always among the preferred characteristics in the surveys of *Capsicum* use in Amazonia. Fonseca *et al.* (2008) detected only three subsamples of *C. chinense* with low pungency in a total of 38 morphologically characterized accessions collected in the upper Rio Negro (Amazonas). In general, larger and heavier fruits have low pungency and are used in Roraima for cooking as sautéed, in this case, scented chili (*C. chinense*); and for salads, especially bell peppers (*C. annum* var. *annuum*) and Brown's pepper (*C. baccatum* var. *pendulum*) (Nascimento Filho *et al.*, 2007). Consumers' choice in relation



**Figure 2.** Average and standard error from scores obtained by factor analysis, where F= forest and S= savanna; IN= indigenous and NI= non-indigenous; R= rural and U= urban (valores médios e erro padrão dos escores obtidos na análise fatorial, onde F= floresta e S= savana; IN= indígena e NI= não indígena; R= rural e U= urbano). Boa Vista, INPA, 2007.

to large fruits lies much more on fruit consistency and morphological dimensions than on pungency (Olarewaju & Aliyu, 1994).

We concluded that it is possible to distinguish between different groups of users (IN and NI) of *Capsicum* peppers in Roraima using morphometric markers, phytophysiology and home zone. The distinction can arise from different crop practices or morphotype adaptation to the environment where it is grown. However, the distinction derived from morphometric markers and the subsequent formation of four classes of users did not provide clear patterns of culinary use by species, morphotypes or fruit color, shape and pungency between the two ethnic groups (IN and NI). Overall, both groups use preferably morphotypes with small, low weight and high pungent fruits (*C. chinense* and *C. frutescens*) for preparing sauces and *jiquitaita* (pepper powder), and large, high weight and low pungent fruits (*C. annuum* var. *annuum*, *C. baccatum* var. *pendulum* and some cultivars of *C. chinense*) for salads and cooking. This can be explained by the historical cultural links between these

two major ethnic groups in Roraima, which results in a two-way exchange of habit and usages and leads to a set of common rules for the preferential choice of *Capsicum* fruits based mainly on the needs for home use.

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