



Variations in the Composition of “Algarrobas” (*Prosopis* sp.) Flours from Paraguayan Chaco [†]

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Abstract: *Prosopis alba* and *Prosopis chilensis*, popularly called carob trees in the South American Chaco, are arboreal species. Carob fruits are an ancestral food for human consumption, mainly in the form of flour. In recent years, the study of carob trees in Paraguay has been based on the development of silvo-pastoral systems for livestock or as animal feed; very little is known about the compositional characteristics of the different varieties of carob that are part of the food systems, and that are used for the production of flours. Samples of flour from three autochthonous varieties of carob trees from the Central Chaco are evaluated for human consumption as a potential food ingredient in processed foods. They are evaluated for nutritional contribution, antioxidant potential and the preliminary evaluation of safety at the microbiological level. Official AOAC methods were used. The carob flour samples presented low humidity (less than 6%) and water activity (less than 0.45). The flours of the three species analyzed presented significant differences in their content of carbohydrates, lipids, proteins, dietary fiber and, consequently, in their caloric value, with a high content of polyphenols and antioxidant potential detected by ABTS. Presence of mesophilic aerobes, total coliforms and yeasts in the samples was observed. These results demonstrate the great food potential of carob flour from the Paraguayan Chaco, and indicate the need to address the food safety aspects of this type of wild-harvested food, to enhance their added value as ingredients for foodstuffs in the diet of regional populations.

Keywords: *Prosopis alba*; *Prosopis chilensis*; algarrobas; composition; flour; autochthon foods; Paraguay



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1. Introduction

It has been reported that *Prosopis* pods can constitute food sources from indigenous systems, such as “patay, arroppe, chicha, aloja” in South America in the Gran Chaco region, where the species of *Prosopis* are native [1]. The genus *Prosopis* belongs to the Leguminosaceae family; its pods are used to obtain a harina, used in an ancestral way by native peoples, which has been shown to have a high nutritional value. The species of *Prosopis* are known by the name of “algarrobas” in the South American Chaco and are used as food, fodder, fertilizer, wood and raw material for the development of various economic activities. Very little is known about the nutritional characteristics of the different varieties that form part of the food systems and are used for the creation of *Prosopis* sp. flour in Paraguay. In the last decades, the importance of these ancestral foods in food security and the sustainability of ecosystems has been recognized [2]. Vulnerable conditions in rural populations, such as food insecurity and malnutrition, motivate the realization of development projects that are sustainable, and that implement alternative raw materials as a food base. In this context, the research of some South American countries have recently included foods such as “algarrobo” flours, which can vary in nutritional composition depending on the species of *Prosopis*, the form of obtaining it and the storage conditions [3]. The aim of this work was to evaluate the nutritional characteristics, the antioxidant potential and the

presence of microorganisms in *Prosopis* sp. flour samples from an autochthonous species of “algarrobos” from the Central Chaco as a potential food ingredient in processed foods.

2. Materials and Methods

2.1. Sampling

Prosopis pods were manually collected from wild trees at Filadelfia, Boquerón, Chaco, Paraguay. They were recognized and stored by a local company and processed to obtain the flours. The three flour samples were made from *Prosopis alba* (white), *Prosopis chilensis* (yellow) and *Prosopis chilensis* (brown) pods (Figure 1) without seeds in successive stages of washing, drying, milling, sieving and potting. The *Prosopis* flour samples were packaged independently, and stored in dark multi-laminated aluminum bags until they arrived at the laboratory.

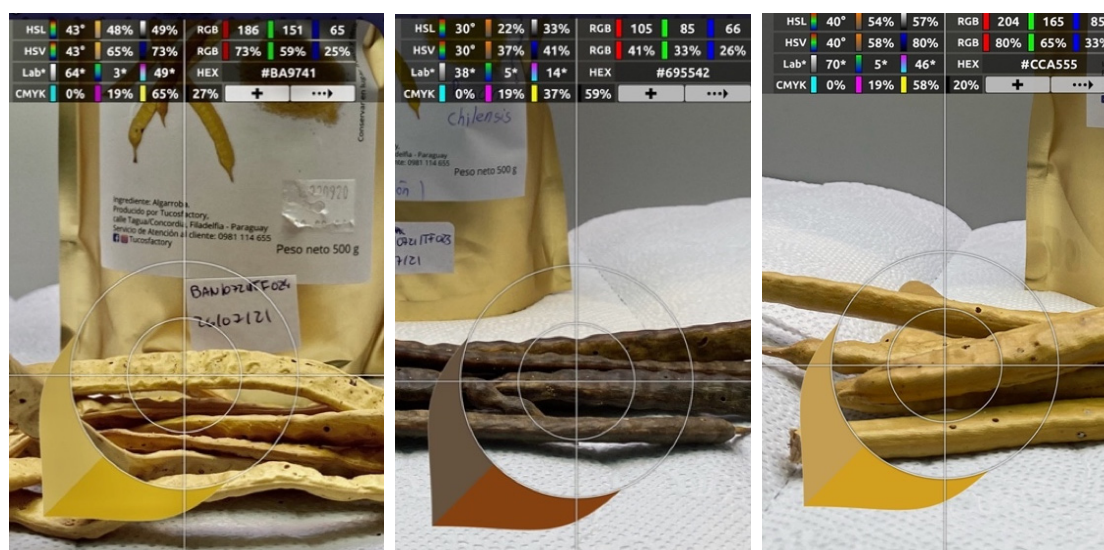


Figure 1. Representation of the pod colors of *P. alba* (white), *P. chilensis* (brown), and *P. chilensis* (yellow).

2.2. Analytical Methods

Prosopis flours were analyzed by official methods as follows; moisture AOCS Ca 2b–08, ash AOAC 900.2, proteins AOAC 979.09, total lipids AOAC 948.22, dietary fiber AOAC 985.29, total carbohydrates by anthrone method, water activity AOAC 978.19, and the caloric value by the Atwater method. Total phenols were determined using the Folin–Ciocalteu method with some modifications based on a colorimetric oxide-reduction reaction [4]. Total Antioxidant Capacity (TAC) by ABTS+ radical cation bleaching assay [5]. The microbial load was determined by Mesophilic aerobic AFNOR 3M 01/01-09/89, total coliforms AFNOR 3M 01/01-09/89, fecal coliforms AFNOR 3M-01/5-03/97 B, Yeasts and Mold count A.O.A.C. 997.02 and were used for analysis.

2.3. Statistical Analysis

The data was recorded and processed in a form of the GraphPad Prism 8.2 program (GraphPad Software Inc., San Diego, CA, USA). To determine significant differences, ANOVA and Tukey’s post-hoc test was carried out and $p \leq 0.05$ was considered significant.

3. Results and Discussion

3.1. Physicochemical Characteristics and Antioxidants

Prosopis flour samples presented low moisture (less than 6%) and water activity (less than 0.45). The water activities of samples were: *Prosopis alba* (white) 0.393 ± 0.003 ; *Prosopis chilensis* (brown) 0.433 ± 0.006 ; and *Prosopis chilensis* (yellow) 0.378 ± 0.009 . The samples

analyzed presented a high content of carbohydrates (48.33–58.13 g/100 g) and total dietary fiber (25.67–32.15 g/100 g) in their composition, with significant differences (ANOVA, Tuckey post test $p \leq 0.05$) in their content of carbohydrates, lipids, proteins, dietary fiber and, consequently, in their caloric value (Table 1). Galera et al. [6] reported higher carbohydrate contents (72.47 g/100 g for *Prosopis chilensis* and 66.69 g/100 g for *Prosopis alba*) in the same species collected in Argentina, while studies carried out in Paraguay [7], Brazil and Bolivia [8] reported similar values of carbohydrates to those observed in this work for samples of same species of *Prosopis* flours (40.3–40.6 g/100 g *Prosopis alba*, 43.8–44.5 g/100 g *Prosopis chilensis*). Sucrose constituted the main sugar for flours obtained from *Prosopis alba* and *Prosopis nigra* [1]. The total lipid content in samples was low, which coincides with other regional studies [7,8] where the lipid content does not exceed 1.7%.

Table 1. Physicochemical characteristics of *Prosopis* sp. flours.

Compounds	<i>Prosopis alba</i> (White)	<i>Prosopis chilensis</i> (Yellow)	<i>Prosopis chilensis</i> (Brown)
Moisture (g/100 g)	5.62 ± 0.22 ^a	4.31 ± 0.31 ^b	4.55 ± 0.37 ^b
Ash (g/100 g)	5.46 ± 0.15 ^a	4.21 ± 0.10 ^c	4.86 ± 0.18 ^b
Total lipids (g/100 g)	1.94 ± 0.18 ^a	2.79 ± 0.10 ^b	2.22 ± 0.22 ^a
Total proteins (g/100 g)	7.31 ± 0.42 ^a	9.41 ± 0.44 ^c	10.70 ± 0.25 ^b
Dietary fiber (g/100 g)	31.06 ± 2.65 ^a	25.67 ± 1.81 ^b	32.15 ± 3.47 ^a
Carbohydrates (g/100 g)	48.33 ± 3.38 ^a	58.13 ± 1.55 ^b	53.37 ± 8.19 ^{ab}
Caloric value (kcal/100 g)	240.01 ± 14.8 ^a	295.27 ± 7.0 ^b	276.26 ± 9.1 ^b

Results are expressed as mean ± SD of three independent assays. Values in the same row with the same superscript letter are not significantly different ($p > 0.05$) as measured by ANOVA and Tukey's post-hoc test, $p \leq 0.05$.

Around 2.9% and 1.4% of soluble proteins were reported, for *P. alba* [1]. The caloric value ranged from 240 to 295 kcal/100 g with significant differences between the means (ANOVA, Tuckey post test, $p < 0.05$). The *Prosopis alba* flour had the lowest caloric value.

The TPC content on *Prosopis* flours samples were 610 ± 31 mg GAE/100 g in *P. alba* (white), 835 ± 82 mg GAE/100 g in *Prosopis chilensis* (brown) and 746 ± 18 mg GAE/100 g in *Prosopis chilensis* (yellow). The samples presented a good antioxidant potential: *P. alba* (white) 21.8 ± 4.07 mM TEAC/g, *P. chilensis* (yellow) 21.6 ± 0.68 mM TEAC/g and *P. chilensis* (brown) 23.1 ± 1.99 mM TEAC/g. It has been reported that the antioxidant potential of the *Prosopis* pods is greater in the dark pods such as *P. nigra* than in the cases of light-colored pods such as *P. alba* [1], which coincides with our findings.

3.2. Microbiological Analysis

Regarding the microbiological analysis of the samples, the results show the absence of fecal coliforms and fungi (Table 2). At the local level, there are no regulations on quality criteria for raw materials or *Prosopis* flour. However, the quantified levels of yeasts and Mesophilic Aerobes indicate the need to address the safety aspects of this type of wild food in future studies, to improve their added value as food ingredients in the diet of regional populations. These results demonstrate the nutritional potential of the analyzed samples, and suggest evaluating safety criteria in current production, to enhance their added value as food ingredients in the diet of regional populations.

Table 2. Microbiological analysis of *Prosopis* sp. flours.

Flour Samples	Recuento de Colonias (UFC/g)				
	Mesophilic Aerobes	Total Coliforms	Fecal Coliforms	Molds	Yeasts
<i>P. alba</i> (white)	6.8×10^3	4.4×10^3	-	$\leq 10^1$	6.0×10^3
<i>P. chilensis</i> (brown)	8.8×10^3	5.0×10^2	-	$\leq 10^1$	4.3×10^3
<i>P. chilensis</i> (yellow)	7.5×10^3	6.1×10^2	-	$\leq 10^1$	5.0×10^3

4. Conclusions

The flours obtained from *Prosopis* pods of different species from the same region can vary in composition of macro and micro components, which can affect the nutritional quality. Therefore, different species of *Prosopis* can present hybrids with different composition. Going forward, with good manufacturing practices, *Prosopis* flours could help to prevent pathologies associated with oxidative stress because they are a non-conventional source of antioxidant compounds.

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