



A Comprehensive Characterisation of Mezquite Seeds “Algarroba” as a Source of Galactomannans of Interest to the Food Industry [†]

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Abstract

The mezquite “algarroba” fruit, produced by species of the *Neltuma* genus in the Gran Chaco Americano region, has historically been used by indigenous communities to produce flour. In Paraguay, the value chain surrounding it is still in its infancy, but there is growing interest in its full utilisation. The seeds, which are commonly discarded as biowaste, contain galactomannans with technological properties that make them a potential natural alternative to commercial hydrocolloids. This study aimed to characterise the physical properties and chemical composition of *Neltuma chilensis* seeds from the Paraguayan Chaco and evaluate their potential as a source of dietary fibre and galactomannans. Physical parameters (weight, dimensions and colour) as well as moisture content, protein, lipid, dietary fibre and mineral content were determined using official methods (AOAC). Available carbohydrates, total sugars and caloric value were also quantified. Galactomannans were extracted with isopropanol using two treatments. Mannose and galactose were quantified using liquid chromatography with a refractive index detector (HPLC/RID). The results revealed high levels of dietary fibre (47.39 ± 2.25 g/100 g) and protein (27.55 ± 2.92 g/100 g) in the seeds, as well as notable concentrations of phosphorus, potassium, and magnesium. No statistically significant differences were observed in the mannose/galactose ratio (1.38 ± 0.02) between the treatments used ($p < 0.05$). Beyond their composition, the technological potential of these seeds supports their use in functional foods that could contribute to digestive and metabolic health. This work provides novel evidence for the revaluation of this traditionally underutilised by-product, in line with strategies for functional nutrition, waste reduction, and the development of a sustainable bioeconomy in the Paraguayan Chaco.

Keywords: *Neltuma chilensis*; non-conventional food plants; native food; biodiversity; biowaste; mezquite seeds



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1. Introduction

Algarroba is an underutilised species not involved in large-scale production and marketing chains in Paraguay. However, it has traditionally been used to produce flour, and there is growing interest in using this fruit to create added value. This has a positive impact, providing multiple opportunities for the industrial sector [1]. Algarroba seeds

(*Neltuma* spp.), which contain soluble dietary fibre known as galactomannans, are generally discarded when algarroba flour is produced. Therefore, this biowaste could be used as an alternative to traditional sources of commercial gums. It is a raw material that is easy to handle and preserve, and it can be used in industry as a potential additive due to its thickening and emulsifying properties [2,3]. Galactomannans are polysaccharides primarily obtained from the seeds of various legumes, including carob (*Ceratonia siliqua*), guar (*Cyamopsis tetragonoloba*), tara (*Caesalpinia spinosa*), fenugreek (*Trigonella foenum-graecum*) and mesquite “algarroba” (*Neltuma* sp.). The content and properties of galactomannans vary depending on the species and cultivation conditions. To produce them, galactomannans must be extracted and purified since, in their natural state, they are associated with other components of the cellular matrix. Extraction methods include thermal, acidic, enzymatic and microwave techniques, each with different efficiencies, costs and purity levels. Furthermore, the current trend in industrial production is to develop more efficient and sustainable processes that maximise performance and preserve functional properties while minimising environmental impact [2,3].

Until now, indigenous communities in the Paraguayan Chaco obtained *Neltuma chilensis* flours from whole pods, discarding the seeds as waste. The aim of this study was to characterise the physical properties and chemical composition of *Neltuma chilensis* seeds from the Paraguayan Chaco and to evaluate their potential as a functional source of dietary fibre and galactomannans.

2. Materials and Methods

2.1. Plant Material

The seeds that are part of the mesquite pods (*Neltuma chilensis*) come from the Pykasu Community of the city of Nueva Asunción located at 20°43'31.8" S, 61°53'0.5" W, in the Department of Boquerón, Paraguay.

2.2. Physical Parameters, Centesimal and Mineral Composition

Physical parameters (weight, dimensions, colour), as well as moisture, proteins, lipids, dietary fibre and minerals, were determined using official AOAC methods [4]. Available carbohydrates and total sugars were also quantified by the antrone method [5], and caloric value was calculated with Atwater's formula [6].

2.3. Extraction and Quantification of Galactomannans

Twenty grams of seeds were weighed in triplicate and hydrated to separate the cuticle, germ and endosperm. The parts of the seed were freeze-dried separately, after which the endosperm was used to extract the galactomannans for subsequent quantification.

One hundred milligrams of galactomannan extract were weighed in triplicate. Hydrolysis was performed using 1 M sulfuric acid and neutralisation was performed using two treatments: barium carbonate (1 g) and calcium carbonate (1 g). The concentration of mannose and galactose sugars was then quantified using high-performance liquid chromatography (HPLC) with an infrared (IR) detector and mannose and galactose standards, according to the AOAC method, to obtain the mannose/galactose ratio [4].

2.4. Statistical Analysis

Trials were conducted in triplicate and the results were expressed as the mean with their corresponding standard deviation. A Student's t-test was performed in RStudio version 2024.09.0+375 to compare the galactomannan extraction yield and the mannose/galactose content, with a 95% confidence interval ($p \geq 0.05$).

3. Results and Discussion

3.1. Seed's Physical Parameters, Centesimal and Mineral Composition

Table 1 shows the results for the longitudinal and transverse diameters, widths, weights and colours of the seeds. Figure 1 shows the sample studied and its parts, as well as the fraction of galactomannans extracted from the seeds of *Neltuma chilensis*. Table 2 shows the results for the centesimal composition, caloric value and mineral content of the seeds. The moisture content of seeds (*Neltuma chilensis*) is 7.2 ± 0.1 g/100 g. Sciammaro published approximate values of 6.11 g/100 g for *N. nigra* and 8.03 g/100 g for *N. alba* [1].

Table 1. Physical characteristics of algarroba seeds (*Neltuma chilensis*).

Parameter		Dry Seeds	Hydrated Seeds
	L Ø (mm)	7.2 ± 0.1	8.82 ± 0.69
	T Ø (mm)	4.1 ± 0.3	5.30 ± 0.48
	a (mm)	2.3 ± 0.1	4.01 ± 0.55
	Seed weight (g)	0.040 ± 0.003	0.11 ± 0.02
Colour	L*	42 ± 4	-
	a*	5.7 ± 0.6	-
	b*	7 ± 1	-

The results are expressed as media $\pm$ SD. (-); No determined. n = 3.

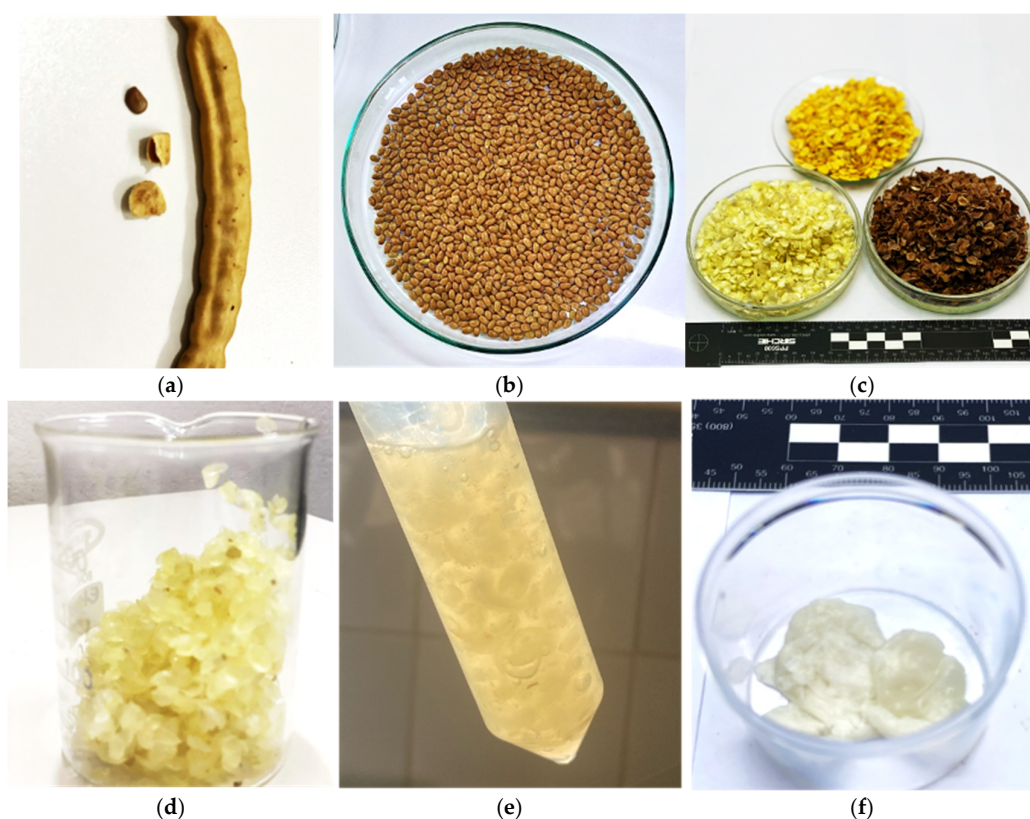


Figure 1. Mezquite “algarroba” seeds (*Neltuma chilensis*), (a) Whole pod, pericarp and whole seed, (b) *N. chilensis* seeds, (c) Hydrated seeds and their separate parts: germ, albumen and testa, (d) Hydrated albumen, (e) Extraction of galactomannans with isopropanol, and (f) Galactomannan fraction from *Neltuma chilensis* seeds.

The total mineral content of the seeds is 3.64 ± 0.09 g/100 g. Ibáñez and Ferrero [7] report a lower value of 3.20% (*w/w*) for *N. flexuosa* seeds. The lipid content of the seeds observed was slightly lower (2.6 ± 0.2 g/100 g) than that reported by Ibáñez & Ferrero [7] in *N. flexuosa* 3.8 g/100 g seeds.

Table 2. Centesimal composition, caloric value and mineral elements content in algarroba seeds (*Neltuma chilensis*).

Parameters	Algarroba Seeds
Moisture (g/100 g)	7.2 ± 0.1
Ash (g/100 g)	3.64 ± 0.09
Dietary fibre (g/100 g)	47 ± 2
Total Protein (g/100 g)	27 ± 3
Total carbohydrates (g/100 g)	13.6 ± 0.5
Sugars (g/100 g)	8.1 ± 0.4
Total lipids (g/100 g)	2.6 ± 0.2
Caloric value (Kcal/100 g)	188 ± 13
P (mg/100 g)	604 ± 8
K (mg/100 g)	385 ± 80
Ca (mg/100 g)	277 ± 20
Mg (mg/100 g)	149 ± 26
Na (mg/100 g)	21 ± 6
Fe (mg/100 g)	9.2 ± 0.3
Zn (mg/100 g)	9.0 ± 0.3
Cu (mg/100 g)	1.3 ± 0.1

The results are expressed as averages and their corresponding standard deviations, n = 3.

Dietary fibre was the main component of the centesimal composition (47 ± 2 g/100 g). The second-highest value in the centesimal composition of the seeds was protein, at an average of 27 ± 3 g/100 g. Ibáñez and Ferrero [7] reported a higher dietary fibre content (54.1 g/100 g) in *N. flexuosa* seeds. Dietary fibre is generally classified according to its solubility in water: insoluble fibre (e.g., cellulose, hemicellulose and lignin) and soluble fibre (e.g., pectin, pectic substances, gums, mucilage and some hemicelluloses). Soluble dietary fibre generally has greater hypocholesterolemic effects and delays glucose absorption [8].

The main mineral element in *N. chilensis* seeds was phosphorus (605 ± 8 mg/100 g). Fabaceae species, such as *Neltuma* sp., have the ability to mobilise phosphorus and other micronutrients into the soil, improving both crop yield and soil structure [9].

Among the minor mineral elements, manganese was found. The value reported for manganese is 1.5 mg/100 g for *N. alba* and 2.2 mg/100 g for *N. nigra* [1], which is higher than the value reported in this study for *Neltuma chilensis* seeds (0.77 mg/100 g).

Notable differences have been observed in the mineral content of the species studied compared to other *Neltuma* spp. studies, reflecting the difference in soil type. For example, a study of *N. alba* and *N. nigra* reported potassium as the main mineral, with an average content of 600 and 640 mg/100 g, respectively [1]. In contrast, an average potassium content of 385 mg/100 g was obtained in the studied samples of *Neltuma chilensis*.

3.2. Extraction and Quantification of Galactomannans

The endosperm of the studied seeds represented 17% of the total weight, of which 5.12% was extracted as galactomannan. The sugar monomer constituents of the galactomannan fraction were quantified by hydrolysis with sulfuric acid and two neutralisation treatments with BaCO₃ (M1) and CaCO₃ (M2). The results are shown in Table 3, where statistically significant differences (Student's *t*, $p < 0.05$) were observed in the neutralisation treatments used. The extract contained between 28.7% and 40.9% mannose/galactose (see Table 3). According to Vilaró Luna, the percentage of galactomannans flocculated from the endosperm of *N. affinis* was 2.49% lower than that obtained in this study [10].

Table 3. Mannose/galactose ratio of extracted galactomannans.

Samples	Mannose/Galactose Extract Yield (%)	Mannose (mg/100 mg)	Galactose (mg/100 mg)	Mannose/Galactose Ratio
M1. Ba	28 ± 1 ^a	16 ± 1 ^a	12 ± 1 ^a	1.37 ± 0.02 ^a
M2. Ca	40.9 ± 0.3 ^b	23.8 ± 0.2 ^a	17.1 ± 0.1 ^a	1.39 ± 0.02 ^a

Note: The table describes the results of the relationship of mannose and galactose, average yield with a Student's *t*-statistical analysis ($p < 0.05$) of the man + gal content (%). Different letters in the averages indicate that there are significant differences between the means.

As previously reported, the extraction yields ranged from 44% to 76% for the acid and alkaline treatments, respectively. The difference in extraction yields can be attributed to the presence of impurities, such as other seed polysaccharides, which are extracted due to the difficulty of separating parts such as the cuticle and seed testa [11]. Regardless of the neutralisation method, no statistically significant differences were observed in the man/gal ratio (1.38 ± 0.02). Oliva et al. [11] performed the extraction of galactomannans from *Neltuma* spp. seeds in Chile. They obtained a ratio of 1.3, which is consistent with the results of this study. However, another study reported a higher ratio of 1.5 in *N. affinis* seeds [10]. This demonstrates the variation in galactomannan composition between different species and highlights the importance of characterising the extracts from these seeds given the significant biodiversity of the Paraguayan Chaco.

4. Conclusions

The dried mesquite “algarroba” seeds (*Neltuma chilensis*) that were studied constitute approximately 8% of the pods and are a bioresidue from the production of “algarroba” flour. The chemical composition of the seeds showed a high dietary fibre content, a high protein content and a low total lipid value. The mannose/galactose extraction yield from the seeds was higher with neutralisation using calcium carbonate (40.9 ± 0.3). However, there were no significant differences in the quantification of the mannose/galactose ratio when using the methods of neutralisation with barium carbonate or calcium. This study provides the first data on the physical characteristics and on the chemical and galactomannan composition of the *Neltuma chilensis* seeds from the Paraguayan Chaco. It also opens up possibilities for a circular economy and the full utilisation of the pod following flour production.

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