



Biodiverse *Neltuma* spp. Pod Flours from the Paraguayan Chaco as Ancestral Sources of Mineral [†]

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[†] Presented at the VII ValSe-Food Congress (Ibero-American Congress of Valuable Seeds) and the IV CICLA Congress (International Congress on Cereals, Legumes and Related Crops), Quito, Ecuador, 7–9 October 2025.

Abstract

One of the main uses of carob pods ‘algarroba’ (*Neltuma* spp.) is flour for direct human consumption in indigenous and rural populations of the Gran Chaco. The flour contains antioxidant compounds such as anthocyanins, flavonoids and alkaloids, the concentrations of which can vary according to environmental and genetic factors of the species. This ancestral food is an excellent nutritional alternative as a gluten-free ingredient with antioxidant potential for various culinary preparations. Minerals have essential functions in the human body, so a balanced diet is key to ensuring adequate intake. The composition of carob beans from the Paraguayan Chaco has been little explored in terms of their mineral nutrient content. The aim of this study was to determine the Fe, Cu, Zn and Mn content of carob meal from different species of *Neltuma* spp. From the Paraguayan Chaco. The mineral elements were determined by atomic absorption spectrometry using official AOAC (2000) methods. Of the samples analysed, *N. ruscifolia* carob flour had the highest content of Zn (2.2 ± 0.8 mg/100 g), Mn (1.6 ± 0.1 mg/100 g) and Cu (1.5 ± 0.4 mg/100 g). *N. nigra* and *N. alba* flour showed higher Fe contents (4 ± 2 and 3 ± 2 mg/100 g, respectively). Consumption of 100 g of *P. ruscifolia* and *P. nigra* meal would cover up to 100% of the Recommended Daily Intake (RDI) for Cu and 55–72% of the RDI for Mn. This implies that carob-based foods from Paraguayan Chaco species could have a protective role against oxidative stress if incorporated as functional foods, as well as representing a natural and bioavailable source of antioxidant minerals, which is especially valuable in diets of vulnerable populations with deficiencies or increased requirements, such as in pregnancy, ageing, or chronic diseases.

Keywords: antioxidant minerals; functional ingredient; *Neltuma*; pods flour



Academic Editors: Pedro Maldonado, Mauricio Mosquera, Norma Sammán, Ma. Carolina Zúñiga-López and Claudia M. Haros

Published: 8 December 2025

Citation: Villalba, R.; Escobar, A.; Coronel, E.; Caballero, S.; Piris, P.; Mereles, L. Biodiverse *Neltuma* spp. Pod Flours from the Paraguayan Chaco as Ancestral Sources of Mineral. *Biol. Life Sci. Forum* **2025**, *50*, 13. <https://doi.org/10.3390/blsf2025050013>

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1. Introduction

The mesquite tree is a staple food for local communities in the Gran Chaco biodiversity region. The pods of different species of the genus *Neltuma* spp., called “algarroba”, are ground to make flour, which is the main way in which the tree is utilised [1]. The presence of antioxidant compounds, such as anthocyanins, flavonoids and alkaloids, has been reported among the minor components with bioactive potential. The concentrations of these compounds vary depending on environmental factors and the species present in the algarroba flour [2].

However, little information is available on the mineral composition of carob flour. Some minerals, depending on their concentration, can act as antioxidants or pro-oxidants. These cofactors of enzymes, such as catalase and superoxide dismutase, the substrates of which are reactive oxygen species, may be associated with the development of diseases [3,4]. In light of the growing prevalence of chronic non-communicable diseases, developing healthy and functional foods with the potential to prevent these conditions could be an effective public health strategy, while also promoting the consumption of locally sourced produce. This study aimed to determine the Fe, Cu, Zn and Mn content of algarroba flour from various *Neltuma* species in the Paraguayan Chaco.

2. Materials and Methods

2.1. Plant Material

In November 2024, pods from five different species of *Neltuma* were harvested from various locations in the Department of Boquerón in the Paraguayan Chaco. A total of 23 samples were collected: six of *N. chilensis* (yellow); four of *N. chilensis* (brown); eleven of *N. alba* (white carob); one of *N. nigra* (black carob); and one of *N. ruscifolia* (viñal). The pods were dried at 40 °C in an oven (Tecnal TE-394/2, Piracicaba/SP, Brazil) for 32 h until their moisture content was less than 5%. They were then homogenised in a Metvisa LAR.2 food processor (Jaraguá do Sul (SC), Brazil) and sieved through a 1 mm mesh sieve.

2.2. Analysis

Method 975.03 (AOAC, 2000) [5]. Was used: one gram of flour was weighed into a crucible, which was then calcined on a hotplate before being placed in a muffle furnace (Naber, D-2804, Nordhorn, Germany) overnight. Wet calcination was used to complete the calcination of organic matter, whereby the ashes were treated with nitric acid to ensure complete mineralisation. The minerals copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) were determined using an AA-6300 atomic absorption spectrometer (Shimadzu, Kyoto, Japan). The results were expressed in milligrams per 100 g of sample.

2.3. Statistical Analysis

The analysis was performed in triplicate. The resulting data were recorded in a Microsoft Excel 2016 spreadsheet (Microsoft Corporation, Redmond, Washington, DC, USA) and processed using GraphPad Prism 7.0 (GraphPad Software, Inc., Boston, MA, USA). Descriptive statistics (mean and standard deviation) were used to express the results for each species. To determine whether there were any significant differences between the means, a one-way analysis of variance (ANOVA) was performed, followed by a Tukey post hoc test ($p < 0.05$).

3. Results and Discussion

Table 1 shows the results obtained from the determination of minerals (Cu, Fe, Mn, Zn) in the different samples by atomic absorption spectroscopy. Of the samples analysed, *N. ruscifolia* flour had the highest content of Zn (2.2 ± 0.8 mg/100 g), Mn (1.6 ± 0.1 mg/100 g) and Cu (1.5 ± 0.4 mg/100 g). Thus, consumption of 100 g of *N. nigra* or *N. ruscifolia* flour covers 100% of the RDI for copper and between 55 and 72% of the RDI for manganese [6].

Table 1. Mineral content in *Neltuma* spp. “algarrobas” flours from Paraguayan Chaco.

Minerals (mg/100 g)	<i>N. chilensis</i> (Yellow Accession)	<i>N. chilensis</i> (Brown Accession)	<i>N. alba</i>	<i>N. nigra</i>	<i>N. ruscifolia</i>
Cu	0.507 ± 0.74 ^a	0.6 ± 0.2 ^{ab}	0.5 ± 0.1 ^a	1.0 ± 0.3 ^{bc}	1.5 ± 0.4 ^c
Fe	3 ± 1 ^a	3 ± 1 ^a	3 ± 2 ^a	4 ± 2 ^a	3.2 ± 0.4 ^a
Mn	0.5 ± 0.2 ^a	0.5 ± 0.1 ^a	0.5 ± 0.4 ^a	1.3 ± 0.2 ^b	1.6 ± 0.1 ^b
Zn	1.3 ± 0.8 ^a	1.3 ± 0.6 ^a	1.6 ± 0.7 ^{ab}	2.8 ± 0.5 ^{ab}	2.2 ± 0.8 ^b

Results are expressed as mean ± SD. Different letters in the same row indicate significant differences by ANOVA, Tukey’s post hoc test ($p < 0.05$).

Flours from *N. nigra* and *N. alba* showed higher iron content (4 ± 2 and 3 ± 2 mg/100 g, respectively). Another study by Freyre et al. [7] on *N. ruscifolia* flour reported lower values (1.62 mg/100 g Cu, 2.54 mg/100 g Fe, 0.84 mg/100 g Mn and 1.48 mg/100 g Zn).

For *N. alba*, the Fe value (3 ± 2 mg/100 g) is lower, and the Cu, Mn and Zn values are similar to those reported by Mereles et al. [8] (Fe 4.51 mg/100 g, Cu 0.48 mg/100 g, Mn 0.3 mg/100 g and Zn 1.62 mg/100 g). Data on the mineral composition of *N. chilensis* and *N. nigra* in the literature are limited. However, in the study by García et al. [9], conducted on *N. laevigata* fruits, lower values of Cu (0.362 mg/100 g), Fe (0.734 mg/100 g), Mn (0.146 mg/100 g) and Zn (0.727 mg/100 g) were found.

The results of the mineral analysis of *Neltuma* spp. Flours demonstrate that these species are significant sources of essential micronutrients, particularly iron, zinc, copper and manganese. In some cases, the values obtained exceed those reported in previous studies and those observed in standard flours, such as wheat flour. When compared with refined wheat flour (*T. aestivum*), the results show similar values for manganese (0.6 mg/100 g), but lower values for zinc (0.8 mg/100 g) and copper (0.33 mg/100 g) [10]. From a public health perspective, Incorporating these flours into food formulations could significantly contribute to preventing micronutrient deficiencies, particularly of iron and zinc, which impact anaemia and cognitive development. These findings highlight the need for further research into bioavailability and the development of processing technologies that preserve these minerals in food matrices. This would enhance the role of *Neltuma* spp. flours as functional ingredients in healthy, sustainable diets.

4. Conclusions

The flour of *N. ruscifolia* is distinguished by its high zinc, manganese and copper content, while the flours of *N. nigra* and *N. alba* have higher iron concentrations. This demonstrates the nutritional complementarity between species. A portion of 100 g of *N. nigra* or *N. ruscifolia* flour provides 100% and 55–72% of the recommended daily intake of copper and manganese, respectively, highlighting their potential as functional ingredients in foods for vulnerable populations with micronutrient deficiencies. In comparison to refined cereals such as wheat, the higher content of these minerals emphasises the need to revalue underutilised indigenous resources from the Paraguayan Chaco in food and nutrition security strategies. Furthermore, as these flours are naturally gluten-free, they are a valuable alternative for designing products for people with coeliac disease or non-coeliac gluten sensitivity, while promoting a more diverse and healthier diet.

Author Contributions: Conceptualization, L.M. and R.V.; methodology, A.E. and S.C.; software, E.C.; validation, R.V., E.C., S.C. and A.E.; formal analysis, A.E.; investigation, P.P., A.E. and R.V.; data curation, L.M. and S.C.; writing—original draft preparation, R.V.; writing—review and editing, E.C.; visualization, P.P.; project administration, L.M.; funding acquisition, L.M. All authors have read and agreed to the published version of the manuscript.

Funding: This project PINV01-168 is co-financed by the Consejo Nacional de Ciencia y Tecnología (CONACYT), with support from the FEEL.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Acknowledgments: The authors would like to thank the VALSE Food Network and Lidia Pérez de Molas, Enrique Benitez León and Carolina Escobar from the Facultad de Ciencias Agrarias at the UNA for their support with sampling.

Conflicts of Interest: The authors declare no conflict of interest.

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