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*Proceeding Paper*

# Paraguayan Cassava, an Ancestral Legacy: A Study of Its Centesimal and Mineral Composition †

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**Abstract**

Cassava (Manihot esculenta Crantz) is the third highest-yielding source of carbohydrates among the world's crops. In Paraguay, it is a staple food in the Paraguayan diet and the second source of starch after corn, with high demand. In this study, the percent composition of 12 cassava accessions from the germplasm bank of the Paraguayan Institute of Agricultural Technology was determined. The percent composition was determined in freeze-dried samples using the methodology of the Association of Official Analytical Chemists (AOAC), and carbohydrates were determined by difference. The results highlight that cassava is composed primarily of water and carbohydrates. It is a moderate source of dietary fiber, low in protein, and fat-free. The moisture, protein, ash, and dietary fiber contents differ significantly ($p \leq 0.01$) among the cassava samples. The cassava accessions evaluated show significant variations among samples in terms of moisture, protein, ash, and dietary fiber, highlighting their diversity and the potential for differential use in food product improvement and development programs.

**Keywords:** cassava; centesimal composition; nutritional diversity

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## 1. Introduction

Cassava (*Manihot esculenta*) belongs to the *Euphorbiaceae* family, characterized by the presence of latex-bearing vessels that secrete a milky latex. Within the *Manihot* genus, some 98 species native to the Americas are recognized; however, only *M. esculenta* is economically important [1,2].

In recent years, numerous new species of Manihot have been described, mainly in Brazil and Bolivia, as well as one in Paraguay, bringing the number of accepted taxa for the genus to about 120 species [2].

Its complete botanical classification includes the division *Magnoliophyta*, class *Magnoliopsida*, order *Malpighiales*, subfamily *Crotonoideae* and tribe *Manihoteae*, placing it within a specific group of plants with common characteristics [3].

Native to South America, cassava was domesticated in a wide region stretching from Mexico to Brazil, where it is estimated to have been first cultivated approximately 5000 years ago. It is widely distributed in tropical and subtropical zones and is cultivated

in approximately 90 countries in the Americas, Asia, and Africa. It is considered a "non-centric" crop because it does not have a single clear center of origin or diversity [1,4].

In Paraguay, the genus *Manihot* is represented by 16 taxa, of which 6 are endemic to the country. Most of these species are distributed in the Eastern region, while only five have been recorded in the Chaco. Paraguay hosts an important genetic reserve for the improvement of this crop; however, knowledge about most of these species, and particularly about their agronomic characteristics, is still very limited. [2].

The aim of this investigation was to evaluate the characterization of the centesimal, mineral composition of cassava (*Manihot esculenta*) from the germplasm bank of the Paraguayan Institute of Agrarian Technology (IPTA).

## 2. Materials and Methods

### *2.1. Raw Material*

The 12 samples analyzed correspond to different cassava (*Manihot esculenta*) accessions provided by the Paraguayan Institute of Agrarian Technology (IPTA), Choré branch, located in the district of Choré, department of San Pedro, Paraguay. The cassava roots were received fresh and frozen until analysis.

### *2.2. Experimental Design*

A triplicate experiment was performed at a laboratory scale, with a previous treatment: the outer skin was removed (peeled). Quadrant sampling was performed to begin lyophilization using LyoQuest equipment (Telstar, Terrassa, Spain) (−40 °C and a pressure between 0.1 and 1.0 mbar). The process lasted approximately five days. After lyophilization, the samples were ground into a fine powder and stored in labeled plastic bags for later analysis (Figure 1). A small amount was taken from the unsampled portion and transferred to a moisture analyzer. Centesimal compositions were analyzed (humidity, carbohydrates, proteins, lipids, fibers), as well as mineral content (sodium, potassium, calcium, iron, and magnesium) and phosphorus content.

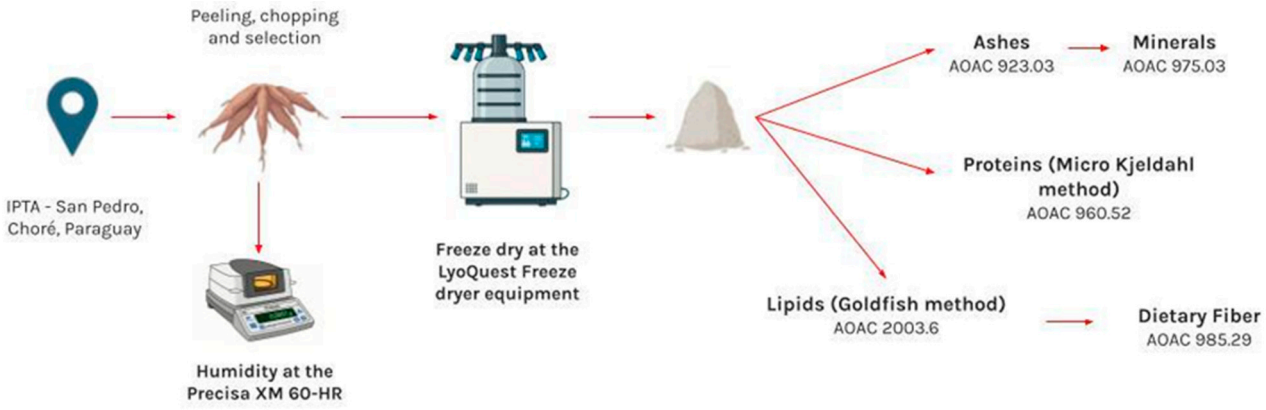



**Figure 1.** General diagram of the centesimal and mineral composition analysis of cassava (*Manihot esculenta*) roots from the IPTA germplasm bank—Choré Branch. Created in BioRender.com (Basic version).

### *2.3. Analysis*

For the Centesimal composition, all the results were expressed in g/100 g: the humidity content was determined by thermobalance using the official method AOAC 32.102 in the model XM 60-HR equipment (Precisa Gravimetric, Dietikon, Switzerland). The ash content was determined using the official method AOAC 923.03 in the muffle model D-2804 equipment (Naber, Lilienthal, Germany). Protein contents were determined using the

official method AOAC (960.52, 12.1.07) in microKjeldahl model K40 equipment (Behrotest, Düsseldorf, Germany). Lipid content was determined using the official method AOAC 2003.06 with Goldfish equipment, TE-044 model (Tecnal, Piracicaba, Brazil). The Fiber content was obtained using the official method AOAC 985.29 with a muffle and microkjeldahl equipment. Carbohydrates were determined by difference, taking into account the results obtained in the other determinations [5].

Minerals (Na, K, Ca, Fe, Mg,) were determined using the official AOAC 968.08 method using atomic absorption spectrophotometry (AAS) in model AA 6300 equipment (Shimadzu, Kyoto, Japan). The phosphorus content was analyzed using the AOAC 970.39 Method, measuring the percentage of transmittance, at a wavelength of 400 nm UV on, model: UV-1800 (Shimadzu, Kyoto, Japan). Results were expressed in mg/100 g [5].

## 3. Results and Discussion

### *3.1. Centesimal Composition*

The centesimal composition of the freeze-dried cassava samples is presented in Table 1. The moisture content ranged from 54.8 g/100 g to 80.1 g/100 g. According to Buitrago A et al. [6], in a study conducted on cassava as animal feed in Cali, Colombia, moisture content usually remained relatively constant at 62% to 68%. However, in this study, some samples showed values higher than this range. It is important to mention that prior to determining the moisture content, the samples were frozen, which could have influenced the results obtained.

**Table 1.** Centesimal composition of cassava samples (*Manihot esculenta*). Expressed in g/100 g.

| Sample | Moisture | Total Carbohydrates | Dietary Fiber | Protein | Ash | Lipids |
|---|---|---|---|---|---|---|
| 109 | $64 \pm 4^{d}$ | $33 \pm 4^{c,d}$ | $3.6 \pm 0.4^{b}$ | $2.14 \pm 0.02^{c}$ | $0.67 \pm 0.04^{c}$ | $0.292 \pm 0.002^{b}$ |
| 154 | $73 \pm 2^{b}$ | $23 \pm 2^{f}$ | $3.0 \pm 0.3^{b,c}$ | $2.91 \pm 0.09^{b}$ | $0.73 \pm 0.02^{c}$ | $0.219 \pm 0.002^{c}$ |
| 212 | $56 \pm 1^{e,f}$ | $38 \pm 1^{b,c}$ | $5.4 \pm 0.5^{a}$ | $4.38 \pm 0.09^{a}$ | $0.86 \pm 0.04^{b}$ | $0.417 \pm 0.002^{a}$ |
| 268 | $66 \pm 2^{c,d}$ | $30 \pm 2^{d}$ | $3.4 \pm 0.3^{b,c}$ | $1.9 \pm 0.5^{c}$ | $0.85 \pm 0.07^{b}$ | $0.35 \pm 0.05^{a}$ |
| 306 | $57.0 \pm 0.6^{e}$ | $39.7 \pm 0.5^{b}$ | $3.5 \pm 0.5^{b,c}$ | $1.9 \pm 0.3^{c}$ | $1.050 \pm 0.008^{a}$ | $0.39 \pm 0.04^{a}$ |
| 575 | $54 \pm 1^{f}$ | $42 \pm 1^{a}$ | $4.9 \pm 0.2^{a}$ | $2.1 \pm 0.4^{c}$ | $0.52 \pm 0.07^{d}$ | $0.39 \pm 0.09^{a}$ |
| 576 | $61 \pm 1^{d}$ | $37.3 \pm 0.9^{c}$ | $2.5 \pm 0.3^{c}$ | $0.91 \pm 0.03^{d}$ | $0.57 \pm 0.04^{d}$ | $0.20 \pm 0.07^{c}$ |
| 577 | $77.4 \pm 0.5^{a}$ | $21.5 \pm 0.5^{f}$ | $1.73 \pm 0.08^{e}$ | $0.62 \pm 0.02^{e}$ | $0.358 \pm 0.008^{e}$ | $0.13 \pm 0.03^{c}$ |
| 578 | $77 \pm 1^{a}$ | $22 \pm 1^{f}$ | $1.97 \pm 0.09^{d}$ | $0.574 \pm 0.009^{f}$ | $0.51 \pm 0.04^{d}$ | $0.04 \pm 0.01^{f}$ |
| 579 | $67.2 \pm 0.5^{c,d}$ | $31.4 \pm 0.4^{e}$ | $2.9 \pm 0.3^{c}$ | $0.7 \pm 0.1^{e}$ | $0.50 \pm 0.03^{d}$ | $0.104 \pm 0.00^{e}$ |
| 635 | $69 \pm 1^{c}$ | $29.4 \pm 0.9^{d}$ | $3.15 \pm 0.03^{b,c}$ | $0.89 \pm 0.04^{d}$ | $0.85 \pm 0.09^{b}$ | $0.114 \pm 0.003^{d}$ |
| 653 | $80 \pm 2^{a}$ | $19 \pm 2^{f}$ | $2.15 \pm 0.07^{c}$ | $0.54 \pm 0.02^{f}$ | $0.28 \pm 0.01^{f}$ | $0.13 \pm 0.01^{c}$ |

Different letters (a, b, c, etc.) in the same column indicate statistical differences according to Tukey's test ($p < 0.05$). Results are presented on a wet basis.

Carbohydrate values were like those reported by the author, who reported an average of 37.5 g/100 g. It is important to consider that the differences observed between samples may be primarily influenced by the percentage of moisture, since this factor directly affects the concentration of the other components [6].

Regarding the dietary fiber values obtained, these were higher than those reported by the aforementioned authors, who recorded concentrations of 1.1 g/100 g, and also noted that generally, dietary fiber values do not exceed 1.5 g/100 g [6]. Other studies indicate that a high fiber content is related to the texture or hardness of the root, as well as its thickness [7]. Therefore, the higher levels could be attributed to differences in root thickness.

According to Buitrago A et al. [6], protein values are comparable to those found in this study, with the exception of sample 212, which reached the highest value (4.38 g/100 g). It is worth noting that, according to the literature, cassava roots are characterized by low

protein levels, and that approximately 50% of the root protein corresponds to protein nitrogen, while the other 50% is made up of free amino acids and non-protein components, such as nitrites, nitrates, and hydrocyanic acid.

Ash concentrations of 1.2 g/100 g are reported in the reference literature; in this study the lower values obtained, ranging between 0.283 and 1.05 g/100 g, can be attributed to factors such as growing conditions and soil type, which directly influence mineral concentration. Regarding lipid content, the reference indicates values of 0.4 g/100 g, comparable to that of the samples analyzed in this work, although in some cases even lower levels were recorded [6].

In general, the centesimal composition of cassava presents relatively constant values; however, they may present minor changes associated with the cassava variety, and the differences between the samples studied could be assumed to be due to their genetic characteristics. These changes have to do especially with the protein, fiber and moisture contents [6].

### 3.2. Mineral Composition

The mineral content of the samples is detailed in Table 2. The potassium content in the cassava samples analyzed in this work is in a similar range to that reported in the literature, where concentrations of 238 and 365 mg/100 g were published in a study conducted at the Australian National University, Canberra [8]. Close values were observed in samples 109, 154 and 212; however, lower levels were recorded in the rest of the samples, with sample 577 showing the lowest value.

**Table 2.** Mineral content of cassava samples (*Manihot esculenta*) expressed in mg/100 g.

| Sample | $K^{+1}$ | $Mg^{+2}$ | $Na^{+1}$ | $p^{+3}$ | $Ca^{+2}$ | $Fe^{+3}$ |
|---|---|---|---|---|---|---|
| 109 | $248 \pm 15^{b,c}$ | $50.7 \pm 0.9^{b,c}$ | $32 \pm 5^{c}$ | $27.5 \pm 0.3^{f}$ | $44.2 \pm 0.8^{c}$ | $0.7 \pm 0.1^{a}$ |
| 154 | $231 \pm 5^{c}$ | $41.5 \pm 0{,}5^{d}$ | $22 \pm 1^{d}$ | $24.4 \pm 0.6^{g}$ | $28.8 \pm 0.2^{f}$ | $0.409 \pm 0.07^{b,c}$ |
| 212 | $326 \pm 50^{a}$ | $55 \pm 2^{b}$ | $36 \pm 7^{b,c}$ | $55 \pm 0.7^{b}$ | $54 \pm 2^{a}$ | $0.4 \pm 0.1^{b,c}$ |
| 268 | $121 \pm 17^{f}$ | $34 \pm 3^{e,f}$ | $42.5 \pm 0.4^{b}$ | $59 \pm 1^{a}$ | $23 \pm 3^{f,g}$ | Nd |
| 306 | $181 \pm 24^{e}$ | $36 \pm 1^{e}$ | $93 \pm 17^{a}$ | $39.8 \pm 0.5^{c}$ | $37 \pm 2^{d}$ | Nd |
| 575 | $157 \pm 25^{e,f}$ | $53 \pm 4^{b,c}$ | $35 \pm 8^{b,c}$ | $25 \pm 2^{g}$ | $28 \pm 2^{f}$ | $0.476 \pm 0.003^{b}$ |
| 576 | $219 \pm 5^{d}$ | $93.6 \pm 0.5^{a}$ | $32 \pm 3^{c}$ | $32.0 \pm 0.4^{d}$ | $17.2 \pm 0.1^{h}$ | $0.352 \pm 0.08^{b,c}$ |
| 577 | $51 \pm 7^{g}$ | $42 \pm 1^{d}$ | $11 \pm 1^{f}$ | $20 \pm 2^{h}$ | $21.2 \pm 0.6^{g}$ | $0.30 \pm 0.03^{c,d}$ |
| 578 | $173 \pm 17^{e}$ | $37 \pm 1^{e}$ | $24 \pm 2^{d}$ | $32.1 \pm 0.5^{d}$ | $11.9 \pm 0.6^{i}$ | $0.34 \pm 0.01^{c}$ |
| 579 | $321 \pm 10^{a}$ | $54 \pm 3^{b}$ | $19.0 \pm 0.8^{e}$ | $39.8 \pm 0.9^{c}$ | $28.7 \pm 0.3^{f}$ | $0.456 \pm 0.07^{b}$ |
| 635 | $255 \pm 10^{b}$ | $33.5 \pm 0.4^{f}$ | $43 \pm 2^{b}$ | $29.2 \pm 0.4^{e}$ | $50 \pm 1^{b}$ | $0.41 \pm 0.08^{b,c}$ |
| 653 | $271 \pm 5^{a}$ | $49 \pm 2^{c}$ | $12 \pm 2^{f}$ | $18.4 \pm 0.9^{h}$ | $32.9 \pm 0.5^{a}$ | $0.26 \pm 0.01^{d}$ |

Different letters (a, b, c, etc.) in the same column indicate statistical differences according to Tukey's test ($p < 0.05$). Results are presented on a wet basis. Nd: Not detectable (values below the method's detection limit).

Magnesium levels were higher than those reported by Howard Bradbury et al. [8]. In that study, magnesium levels of 30 mg/100 g were recorded; although some individual values are close to those reported in the reference work, such as those observed in samples 268, 306, 578, and 635, the remaining samples show significantly higher concentrations.

Regarding sodium concentration, only samples 653 and 577 showed values like those reported in previous studies conducted by the Department of Agriculture in Nassau, Bahamas, which obtained a level of 11.33 mg/100 g. In contrast, the other samples showed concentrations higher than those reported in the literature [9].

The results obtained for calcium were similar to those reported by Danso KE et al. [10], in Legon, Ghana. In that study, the authors worked with an improved cultivar and recorded levels of 42 mg/100 g, comparable to sample 109 (44.2 mg/100 g) in this study. Similarly, in

the same study, local cultivars were analyzed, where calcium levels of 12.3 mg/100 g were observed, comparable to sample 578.

The iron levels determined in this work were similar to those reported by Bolaños Benavidez M et al. [11], in the Technical Recommendations Manual for its cultivation in the department of Cundinamarca, Colombia, who reported approximate values of 0.6 mg/100 g.

The amount of phosphorus determined in the analyzed samples coincides with that reported in the literature, where values between 31 and 61 mg/100 g were reported [8]. However, in some samples, concentrations were lower than those indicated in the reference study were observed.

While some of the mineral profile results obtained in this study coincide with values reported in the literature, while others differ, it is important to consider that each cassava sample has its own characteristics determined primarily by genetic factors. Since all samples were grown under controlled and uniform conditions, it is not possible to attribute the observed variations to differences in growing conditions. Furthermore, most of the minerals are found in the cassava peel. Therefore, if the peel was not completely removed when peeling the root, the mineral concentrations determined may have been altered [6]. The intake of these minerals plays key roles in health, so understanding their variations is essential to assessing their true contribution to the diet.

## 4. Conclusions

The centesimal composition of the analyzed samples was characterized using the AOAC methodologies applied, revealing differences among them. The mineral content in the freeze-dried cassava samples was determined, revealing the diversity of concentrations present in each sample.

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