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Proceeding Paper

Physicochemical and Nutritional Characterization of Paraguayan Organic *Moringa oleifera* Leaves as a Food Ingredient †

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Abstract: Knowledge of the physicochemical characteristics of organic moringa leaves, such as the color, the moisture control and water activity (aw) for biological control, as its basic composition, provides valuable starting data for its improvement and quality control through the selection of key parameters for the conservation of its multiple nutritional and antioxidant qualities in organic production systems adapted to local conditions. Objective: Describe the physicochemical characteristics and composition of macro- and micronutrients of *Moringa oleifera* leaves from a vivarium under controlled conditions and evaluate the antioxidant potential of dried moringa leaves from organic production in Paraguay under experimental conditions. A systematic sampling of moringa leaves from a vivarium was carried out. For color analysis, the CIEL*a*b* coordinates were determined. For physicochemical characteristics' analysis and macro- and micronutrient composition, official methods were used, while Total Phenolics Compounds (TPC) were determined by the Folin Ciocalteau method, and the Total Antioxidant Capacity (TAC) was determined by the antioxidant inhibition test (Radical ABTS+). Under experimental conditions, the dried moringa leaves under experimental conditions presented a light green color and low levels of humidity (8.1 ± 0.4%) and a_w (0.59), with high protein levels (27%), micronutrients such as minerals (Ca, Mg, P, Fe, Zn), vitamins B1, B2, Vit. C, TPC (5051 ± 168 g GAE/100 g) and antioxidants (468 ± 109 mMTEAC/g). Moringa leaves from Paraguay represent a source of micronutrients in the diet, and can be applied as ingredients in different culinary preparations within the framework of a healthy and sustainable diet, in accordance with the Sustainable Development Goals (SDGs).

Keywords: composition; characterization; *Moringa oleifera*; organic; nutrition; micronutrients

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1. Introduction

The growing global population requires the development of efficient, inclusive, resilient and sustainable food systems. This compels innovation in the development of new approaches to promote and consume nutritious foods, adapted to the conditions of climate change, while respecting the environment and the traditions of vulnerable populations [1]. This challenge also involves the resilience of livelihoods and the revaluation of underutilized species with ancestral uses. In this context, *Moringa oleifera* leaves have

been recognized since ancient times as a source of protein and other important nutrients such as vitamins and minerals [2]. Its cultivation is known for its ability to produce a high yield with a less carbon-intensive footprint compared to other crops [3]. It adapts well to warm climates with a limited water supply, making it a potential alternative crop in Paraguay [4]. Understanding physicochemical characteristics such as its leaf color, and implementing biological controls, such as humidity and water activity, along with its basic composition, provides valuable initial data for its enhancement and quality control [5]. This can be achieved through the selection of key parameters to conserve its numerous nutritional and antioxidant qualities within organic production systems tailored to local conditions. The aim of the work was to describe the physicochemical characteristics of moringa leaves from organic production in Paraguay from a nursery under controlled conditions, as well as their nutritional properties and antioxidant potential, based on their percentage composition, minerals, water-soluble vitamins, total polyphenols compounds and total antioxidant capacity (TAC).

2. Materials and Methods

2.1. Sampling

A systematic sampling of moringa leaves from a nursery with an organic fertilization system was carried out in Paraguay. For the analytical determination of nutrients and antioxidants, fresh moringa leaves were dried on the same day as harvest using a convective drying system in trays (50 °C-8 h) in an conventional oven [4].

2.2. Physical and Chemical Characterization

For the color analysis, the CIEL*a*b* coordinates were determined using a Spectrophotometer (TS7600 BOYN Co., Hangzhou, China) with a reference illuminant D65 and a 2° observer. Physicochemical characteristics and were composition of macro- and micronutrients as minerals and vitamins were determined using the official methods of the Association of Official Agricultural Chemists AOAC [6]. For vitamin C, the spectrofluorometric AOAC method 967.22 was used; minerals (P, Ca, Fe, Zn, Mg, Cu) were determined by the atomic absorption spectrophotometry AOAC method 975.03; TPC content was determined by the by Folin–Ciocalteau method [7] and the total antioxidant capacity was analyzed by $ABTS^{\bullet+}$ radical cation-based assay (2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) [8].

3. Results

The fresh moringa leaves had 14.5% moisture on the day of harvest; when they were dried, this decreased to 8.05%, which makes the resulting product non-perishable. The color results obtained in fresh and dry leaves are presented in Table 1. Under the air-drying conditions used, it was observed that storage leads to a significant alteration in the "b" value, while this is not significant for the "L" and "b" values (Student *t* test, $p < 0.05$). This results in a minor shift in the green hue, which is imperceptible to the naked eye.

Table 1. Physicochemical characterization of organic dry leaves of *Moringa oleifera* Lam.

Samples	Color			Moisture	aw
	L*	a*	b*	g/100 g	-
Dry leaf 1	56.66 ±0.15 [a]	−5.26 ± 0.020 [a]	20.97 ± 0.13 [a]	9.10 ± 0.10 [a]	0.58 ± 0.01 [a]
Fresh leaf 1	57.09 ±0.89 [a]	−6.10 ± 0.19 [b]	21.46 ± 0.29 [a]	14.50 ± 0.10 [b]	0.98 ± 0.01 [b]

L* indicates the brightness, and a* and b* are the chromatic coordinates. Results are expressed as mean ± standard deviation. aw: water activity. Values with the same letters as columns indicate that there is no significant difference (Student *t* test, $p < 0.05$).

Composition of Dry M. oleifera Leaves

The centesimal composition of the dried moringa leaves from organic production showed high protein content (26.77 ± 0.52 g/100 g), as well as high levels of dietary fiber (21.54 ± 0.30 g/100 g) and total carbohydrates (20.15 ± 0.47 g/100 g), where 12.49 ± 0.91 g/

100 g corresponds to soluble sugars. A low lipid content (7.16 ± 0.13 g/100 g) was observed (Table 2). The high ash content (10.64 ± 0.07 g/100 g) demonstrates an equally important contribution of minerals, including calcium (2620 ± 210 mg/100 g) and magnesium (362 ± 55 mg/100 g). It also provides significant amounts of phosphorus, iron, zinc, copper and manganese, with a low sodium content (Table 2). Regarding the content of antioxidants and vitamin micronutrients, high concentrations of total polyphenols (5051 ± 168 g GAE/100 g) and total antioxidant capacity (468 ± 109 mM TEAC/g) were observed in the dry leaves, as well as a good supply of vitamin C (23.54 ± 3.51 g/100 g), and riboflavin (23.54 ± 3.51 mg/100 g).

Table 2. Centesimal composition, caloric value, mineral content, water-soluble vitamins and antioxidants on organic dry leaves of *Moringa oleifera* Lam. harvested in Paraguay.

Centesimal Composition	Mean ± SD	Minerals	Mean ± SD
Moisture (g/100 g)	8.05 ± 0.39	Calcium (mg/100 g)	2620 ± 210
Proteins (g/100 g)	26.77 ± 0.52	Phosforus (mg/100 g)	367 ± 1
Total carbohydrates (g/100 g)	20.15 ± 0.47	Magnesium (mg/100 g)	362 ± 55
Sugars (g/100 g)	12.49 ± 0.91	Iron (mg/100 g)	21.87 ± 6.73
Total lipids (g/100 g)	7.16 ± 0.13	Sodium (mg/100 g)	12.26 ± 2.42
Ash (g/100 g)	10.64 ± 0.07	Zinc (mg/100 g)	7.07 ± 0.38
Dietary fiber (g/100 g)	21.54 ± 0.30	Potasium (mg/100 g)	4.23 ± 1.35
Valor calórico (Kcal/100 g)	252 ± 3	Cupper (mg/100 g)	3.42 ± 0.41
		Manganese (mg/100 g)	3.00 ± 0.19
Vitamins		Antioxidants	
Ascorbic acid (mg/100 g)	47.00 ± 3.17	Total phenolics compounds	
Riboflavin (mg/100 g)	35.81 ± 5.46	(mg GAE/100 g)	5051 ± 168
Tiamin (mg/100 g)	0.77 ± 0.02	ABTS (mM TEAC/g)	468 ± 109

Results are expressed as mean ± standard deviation, g; grams, mg; miligrams, Kcal; kilocalories, GAE; galic acid equivalents, mMTEAC; milimoles equivalents of TROLOX.

4. Discussion

One of the most important sensory parameters for the acceptance of dry foods such as moringa leaf powder is color, which is essential for the acceptance of the product. Under the drying test treatment used, a darkening of the leaves was observed, which, due to the high content of beta carotene (yellowish color), are sensitive to heat, light and oxygen. Oven-drying treatments at 50 can also lead to significant color variations due to the carbohydrate contents. Low-molecular-weight carbohydrates are generally lost during heating, which can occur due to the rapid caramelization of the sugar at high temperatures. These variations are usually not significant when processes such as microwave-drying or freeze-drying are used, which increase production costs [5]. The effect of the drying treatments on the protein content is not significant from 40 to 60 degrees and the protein, carbohydrate and fat contents of dried Moringa leaves (4–11% moisture) increase by 3–4 times compared to fresh leaves due to the increase in dry matter [9]. The results observed in organic moringa leaves harvested in Paraguay show similar values to those reported in the literature, with a high contribution of proteins, carbohydrates and minerals. Likewise, the contribution of antioxidants and micronutrients stands out in the evaluated samples [10]. The potential nutritional value of dried moringa leaves from organic production in Paraguay suggests that they are an interesting alternative, which could be inserted as an ingredient in value-added products in formulations that are acceptable to consumers as a dietary supplement. Sensory evaluation studies on foods with dried moringa leaves and their nutritional contribution are necessary to insert them into the regional diet.

5. Conclusions

The dried, organically produced moringa leaves that were analyzed have high levels of vegetable protein, micronutrients such as minerals, vitamins, and other compounds of interest such as antioxidants. Moringa leaves in Paraguay can represent a source of micronutrients in the diet and be applied as ingredients in different culinary preparations within the framework of a healthy and sustainable diet, in accordance with the Sustainable Development Goals.

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