



Honey from a protected area in Uruguay: potential discriminatory parameters for geographical origin

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INTRODUCTION

Apis mellifera honey is a concentrated aqueous mixture composed of many organic and inorganic compounds such as carbohydrates, water, polyphenols, volatiles compounds, minerals, enzymes, amino acids, vitamins. These bioactive compounds not only enhance the nutritional quality of honey and contribute to its aroma and flavor, but also increase its functional value by providing antioxidant, anti-inflammatory, and antimicrobial properties. The honey composition also varies according to geographical origin, floral resources, area of collection, climate and harvesting season.

Montes del Queguay (Uruguay) is a protected area of 20,000 hectares located to the east of the department of Paysandú, where different ecosystems are observed: bath, grassland, lagoons and gallery forest. (Figure 1). This region is the largest natural forested area in Uruguay, making it favorable place for beekeeping activities to produce honeys from native flora. This work presents the results of the combined effects (multivariable analysis) of melissopalynological analysis, physicochemical analyses, and mineral content on honey samples from native flora produced in the study area. Uruguay is among the top main 20 honey exporters in the world, with a production of nearly 12,000 tons, of which 90% is destined for the international market. Almost all exports are made in bulk and without differentiation, which has generated a considerable gap in prices when compared to other exporting countries. This protected area hosts a diverse range of ecosystems that influence the composition and quality of honey, enhancing its unique botanical and geographic identity.



Fig 1. "Montes del Queguay, Uruguay" Photo: GFL/Javier Revuelta



MATERIALS AND METHODS

Thirty honey samples (N=30) collected during the summers of 2022 and 2023 were analyzed. Pollen content was assessed using conventional melissopalynological methods described by Louveaux et al. (1978) (1), which are internationally accepted. Physicochemical parameters were determined according to the official methods of the AOAC (2) and the harmonized technical standards of the MERCOSUR countries for honey identity and quality (3). Mineral content was quantified using a microwave plasma-atomic emission spectrometer (Agilent 4210 MP-AES) (4). Statistical evaluation was performed by one-way ANOVA considering year as factor ($p < 0.05$), followed by Tukey's test ($p < 0.05$). Principal component analysis (PCA) was applied to the 30 georeferenced honey samples from apiaries located in Montes del Queguay (Uruguay) to explore potential associations between physicochemical parameters (ash content and electrical conductivity) and mineral composition across the two sampling years. Data analyses were conducted in R version 4.5.1.

RESULTS AND DISCUSSION

A total of 84 pollen grain types from 32 species were identified, with a predominance of the families *Rhamnaceae*, *Myrtaceae*, and *Combretaceae*. In more than 60% of the analyzed samples, the native species *Scutia buxifolia* ("Coronilla"), *Blepharocalyx salicifolius* ("Arrayán"), and *Terminalia australis* ("Palo amarillo") (Fig 2) accounted for over 70% of the pollen spectrum. Figure 3 illustrates the distribution of the dominant pollen types recorded over two years, which together account for 70% of the pollen assemblage that could define the honeys of the study area.

Predominant Native Flora in Montes del Queguay Honeys



Fig 2. Dominant flora



Fig 3. Accumulated pollen type

Table 1 summarizes the yearly mean values of the parameters studied. Most of the honeys analyzed were characterized by high electrical conductivity ($>800 \mu\text{S}/\text{cm}$), representing a potential marker of their regional origin. Potassium was the most abundant mineral (representing 90% of the minerals studied), followed by calcium, magnesium and sodium. Trace element analysis revealed the presence of copper, while zinc concentrations fell below the detection limit (Fig. 4). The PCA showed that 82% of the data variability is explained by the first two dimensions (Dim1 + Dim2). Quadrant I grouped together the variables: % ash, conductivity, potassium and copper, indicating a strong positive correlation between them. This reflects that the mineral content of honey, particularly potassium, is closely associated with conductivity and % ash. Thus, these variables provide essential information for the characterization of these honeys.

	Conductivity ($\mu\text{S}/\text{cm}$)	Ash (%)	K (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	Cu (ppm)	Zn (ppb)
2022	876,90 $\pm$ 4,36 a	0,543 $\pm$ 0,018 a	2694,02 $\pm$ 19,15 a	114,95 $\pm$ 7,03 a	73,27 $\pm$ 0,33 a	25,11 $\pm$ 0,88 a	0,8338 $\pm$ 0,0003 a	$\leq$ 0,4 a
2023	992,69 $\pm$ 6,98 b	0,519 $\pm$ 0,027 a	2711,10 $\pm$ 15,14 a	150,76 $\pm$ 6,89 a	96,46 $\pm$ 0,54 a	46,76 $\pm$ 0,60 b	0,7202 $\pm$ 0,0038 a	$\leq$ 0,4 a
	mean $\pm$ SD, different letters indicate stat. differences $p < 0,05$							

Table 1. Parameters per year

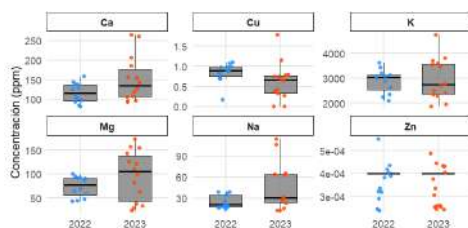


Fig 4. Boxplot Minerals per year

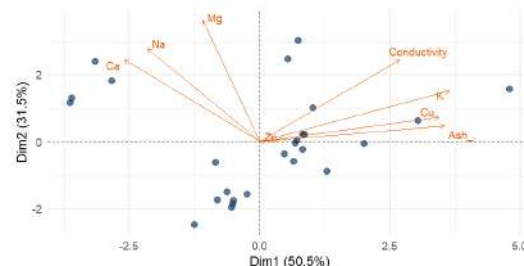


Fig 5. PCA 2022-2023

CONCLUSIONS

The high potassium (K) and calcium (Ca) content, together with the low sodium (Na) concentration and consistently high conductivity values, can be considered discriminatory parameters for the honeys analyzed. These findings contribute to the characterization of honeys derived from native species of the Montes del Queguay, providing valuable indicators of geographical origin and supporting the potential to enhance the international market value of Uruguayan honeys. Continuous sampling during 2024 and 2025 will provide data from consecutive harvests, allowing for a more robust assessment of the viability of a geographical designation of origin



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Uruguay is among the top main 20 honey exporters in the world, with a production of nearly 12,000 tons, of which 90% is destined for the international market. Almost all exports are made in bulk and without differentiation, which has generated a considerable gap in prices when compared to other exporting countries. Paysandú Province is the second-largest honey-producing area in Uruguay, where one of the protected native forest areas, Montes del Queguay, is located. This protected area hosts a diverse range of ecosystems that influence the composition and quality of honey, enhancing its unique botanical and geographic identity. However, only limited studies have been conducted on the characterization of Uruguayan honeys, particularly those from protected areas. Therefore, this study aimed to explore the relationships between botanical origin, physicochemical properties, and mineral content in honeys primarily sourced from native species in Montes del Queguay.

Thirty honey samples were collected from georeferenced apiaries during 2022 and 2023 seasons. Their pollen composition, physicochemical parameters (ash content and electrical conductivity), and mineral content (K, Na, Ca, Mg, Cu, and Zn) were analyzed. Pollen analysis revealed that native species such as *Scutia buxifolia*, *Blepharocalyx salicifolius*, and *Terminalia australis* predominated in most samples. Ash content ranged from 0.362±0.028% to 0.795±0.015%, while electrical conductivity varied from 693.20±8.95 to 1,217.67±9.71 µS/cm. Most analyzed honeys exhibited high electrical conductivity (above 800 µS/cm), a property which may serve as a distinguishing characteristic of honey from this region.

Potassium (2702.56±17.15 mg/kg) was the most abundant mineral among those evaluated, followed by calcium (132.86±7.03 mg/kg), magnesium (84.86±0.44 mg/kg), and sodium (35.93±0.74 mg/kg). Additionally, copper (0.777±0.002 mg/kg) and zinc (≤0.4 µg/kg) were detected in all honey samples at low concentrations. The high potassium and calcium contents, as well as the low sodium concentration, could also be considered as discriminatory parameters of the honeys produced in Montes del Queguay. These findings help characterize honeys derived from native species in Montes del Queguay, offering valuable geographical origin indicators that can support Uruguayan beekeepers in increasing their products' value in the international market.