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Characterization of argentine honeys based on odour, colour and flavour attributes by descriptive sensory analysis

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Abstract: Argentina is one of the world's largest producers of honey. It shows great botanical and geographical diversity that allows producing honey with varied sensory characteristics. Honey samples belonging to Buenos Aires, Catamarca and Misiones provinces (Argentina) were analyzed and typified by their odour, colour and flavour. Sensory attributes depend on phytogeographic origin. No differences were found in sensory analysis beneath years for each province, however significant differences in colour were found between provinces, indicating a distinctive floral composition throughout space. Lighter honeys are produced in Buenos Aires; whereas Misiones and Catamarca produce darker ones. Even though half of Catamarca territory is used for honey production, it yield a wide diversity of honey characteristics related to different ecoregions and several microclimates, making honeys produced indistinguishable from those of the other two provinces studied. A Protected Designation of Origin (PDO) of a broader area for Catamarca province, as Catamarca and Yungas region will solve this problem. Sensory analysis allows making distinctions between phytogeographic regions, fundamentally due to their different flora. A certified PDO will provide honeys with an added value and allow them to access new markets with higher commercial value than standard quality ones.

Keywords: Geographical origin, Multifloral honeys, Sensory profile, Phytogeographic Province (PP), Protected Designation of Origin (PDO)

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Introduction

Argentina is worldwide one of the largest producers of honey. Its position has remained within the top three, being the second global exporter in 2021 (Organizacion Internacional Agropecuaria (OIA), 2022). Argentinian honey represents 70% of the honey produced in the southern hemisphere of the American continent, 25% of the production of the entire continent, and 6% of the total produced in the world (Poliero et al., 2022). Approximately 95% of Argentinian honey is exported as non-differentiated product without any regard to its provenance of origin at the regional level (Fechner et al., 2020; Ministerio de Agroindustria, 2012). Indeed, the wide botanical and geographical diversity and the varied ecosystems and climatic conditions in Argentina leads to the production of a wide variety of honeys, allowing beekeepers to obtain honey with diverse sensory characteristics, differentiating themselves from other honey competitors' producer countries.

Sensory analysis of a product is the evaluation of the perceptible organoleptic attributes, such as colour, odour, taste, touch, texture and noise (Piana et al., 2004). Honey's aroma has been used in Europe since 1970 and, currently it is still used in some countries of South America such as Argentina and Uruguay. This characteristic is used as an analytical tool for the quality control of honeys in relation to their botanic origin as well as a means for the recognition of problems, like fermentation, presence of impurities and other undesirable characteristics that common laboratory routine analyses do not access (Marcazzan et al., 2017).

Honey taste and odour are fundamentally influenced by their botanic origin. Hence, in addition to the elementary tastes (sweet, acid, bitter and salty), also other scents/aromas appear, grouped in seven families: floral, fruit, warm, aromatic, chemical, vegetable and animal, including scents notes like spicy, resinous, menthol, alcoholic, medicinal, caramelized, smoked and resinous (Bruneau et al., 2000; M. Ciappini et al., 2013; Piana et al., 2004). Appearance attributes such as colour and texture are also considered in the honey's sensory characterisation.

Honey colour depends on its alkalinity, ash content and antioxidant compounds, such polyphenols, terpenes and carotenoids (Naab et al., 2008; Viuda-Martos et al., 2010; Wilczyńska, 2014). Thus, honey colour is considered as an index of its antioxidant capacity, since generally dark honeys present higher amounts of phenolic compounds and antioxidant activity, whereas the opposite occurs in light honeys (Alves et al., 2013; Machado De-Melo et al., 2017; Özcan & Ölmez, 2014; Rosa et al., 2011). Since the antioxidant compounds come from the flowers that feed honeybees, the colour of honey can provide information related to its botanical origin (Aazza et al., 2018; Anjos et al., 2015; Naab et al., 2008; Szabó et al., 2016).

Organoleptic characteristics of honeys are defined by their botanic origin and by the nectar collected by the honeybees, therefore a classification by organoleptic test is a fundamental value, being a high contribution along with physicochemical and palynologic data in the characterization of honey (Juan-Borrás, 2016). As it is established by the Directive 110/2001 of the European Union, honey can be defined by its botanic origin, by its palynologic and physicochemical characteristics, as well as its botanic sensory characteristics. Thus, the botanic or geographic characterization of honey, especially as export products, will provide added value once a territorial designation of origin is achieved (Acquarone, 2004; Cayú, 2017; C. Ciappini et al., 2009; Montenegro et al., 2008; Telleria, 2010).

Due to the large extension of its territory, the Republic of Argentina has a broad diversity of climates, environments and types of soil, so there is a wide variation in the vegetation features in so much that it contains 5 Domains with 13 Phytogeographic Provinces (PP) distributed in 24 geopolitical provinces, each one of them can include from 1 to 6 different regions in their territory (A. Cabrera, 1976). Such is the case of the geopolitical provinces of Misiones, Buenos Aires and Catamarca, to reference the phytogeographic origin of the analyzed honeys; the physiognomic-floristic division of Oyarzabal et al. (2018) was used. These authors redefined the regions described by A. Cabrera (1976) generating divisions that they called Vegetation Units (VU).

Misiones province (25°–28° S, 53°–56° W) is located in the country's extreme northeast, under a wet subtropical climate with warm and humid summers, mild winters and abun-

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dant, constant and regular rainfall. These characteristics lead to evergreen vegetation and high biodiversity. Misiones province includes two Phytogeographic Provinces (PP Paranaense and PP Pampeana) and two Vegetation Units (VU) (Oyarzabal et al., 2018; Poliero et al., 2023).

The province of Buenos Aires, situated in the middle-east of the country (33°–41° S and 57°–63° W), is the main honey-producing province, accounting for more than 50% of the Argentinian honey production with around 915.000 beehives (Poliero et al., 2022). The province of Buenos Aires presents several Phytogeographic Provinces (PP), districts and vegetation units (Oyarzabal et al., 2018), as well as different climates. The major honey production areas belong to: (i) PP Pampeana, where the dominant vegetation type is the steppe or pseudo-steppe combined with grassland; (ii) PP Espinal with the sclerophytic forest and the savannah, including arboreal and shrub species, xerophytic mimosoides legumes and an herbaceous layer as the main vegetation types; and (iii) PP Monte, presenting the steppe of xerophytic shrubs with perennial and resinous foliage as the predominant vegetation, and characterized by a shortage of grasses and trees (A. L. Cabrera & Zardini, 1978; Malacalza et al., 2007; Oyarzabal et al., 2018; Poliero et al., 2022).

Finally, Catamarca province (25°–30° S, 65°–69° W) located in the Argentina northwest region (NOA), offers a unique opportunity for apiculture, since it is an area of reduced anthropogenic activity with native flora of different vegetation units (VUs), with 6 PP (Alto andino, Prepuna, Puneña, Monte, Chaqueña and Jungla) that offer a great diversity of flora and climate (Alonso-Salces et al., 2023; Oyarzabal et al., 2018; Vergara-Roig et al., 2019). Catamarca province represents 0.5% of the Argentinian apiaries and 1.1% of the Argentinian honey producers (Poliero et al., 2022). Buenos Aires and Misiones regions show fairly uniform climate conditions, whereas the different PP recognized in Catamarca exhibit several microclimates from the subtropical rains in the East, to the arid highland in the West (Arana et al., 2017) which influence honey characteristics. The aim of this work is the sensory characterization of a set of Argentinian honeys from the provinces of Buenos Aires, Misiones and Catamarca, with the purpose of typifying the honey produced in these phytogeographic regions. Honey characterization from different botanical and/or geographical origins is highly relevant to the honey market since every region present particular quality characteristics determining high commercial value.

Materials and Methods

Honey samples
Eighty-five ($N = 85$) authentic and traceable multifloral *Apis mellifera* honey samples were ocollected from the Argentinian provinces of Buenos Aires ($n = 31$), Catamarca ($n = 26$) and Misiones ($n = 28$) along several harvests (2015-2016-2017). Samples, about 1 kg of raw honey each, were provided directly by beekeepers and/or honey producer cooperatives with farming information (harvest date and conditions, declared botanical origin, apiary location (GPS), agricultural system and beehive treatments). All honey samples met the specifications of the national and international standards, which confirmed their blossom origin, high quality, good maturity and freshness. The honeys were harvested between November and May and manufactured following the guide for good beekeeping and manufacturing practices provided by the Ministerio de Agricultura, Ganadería y Pesca (2019). All honey samples were stored in screw-capped plastic containers at 4 °C in dark settings until analysis, performed immediately after each harvest season.

Sensory analysis

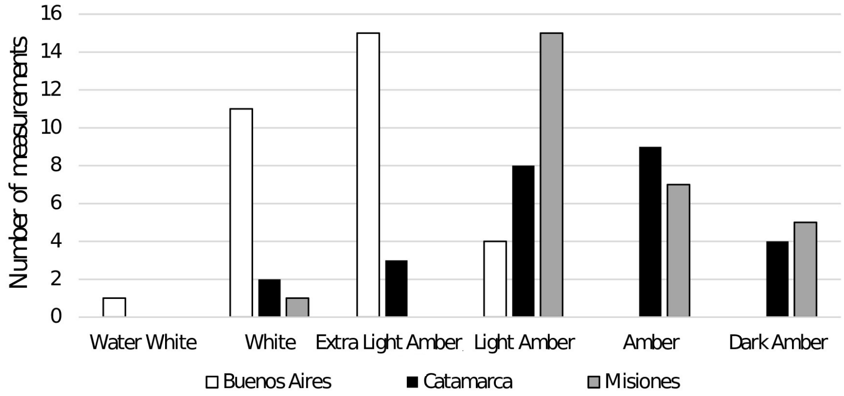

Figure 1: Colour frequencies of honeys classified by province

The quantitative descriptive sensory analysis (QDSA) was carried out by a panel of 7 evaluators trained for this type of products (Sánchez-Pascua et al., 2017). All the tests were carried out in duplicate and in accordance with the sensory evaluation guidelines (ISO 6658, 2005). Tests were performed in individual odour-free cabins. Three different honey samples were given per session to each evaluator. Samples were coded with 3-digit random numbers and divided into 90 g glass jars, keeping a sample/volume ratio of 1/5 (Piana et al., 2004). Samples were kept at room temperature for at least two hours prior to tests.

Odour/Flavour attributes

To evaluate and quantify the intensity of the odour and flavour attributes (sweet, acid and bitter), a structured 12-point scale was used, corresponding 0 to undetectable and 12 for very intense. The standardized terminology developed in the Odour and Aroma Wheel of the International Honey Commission was used as a framework of reference to sensory defines the honeys in terms of smell and flavour (Piana et al., 2004). Odour notes of each different families (warm, aromatic, floral, fruit, vegetable, fresh, chemical and degraded) and subfamilies present in honey due to their botanical origin or as a result of the extraction and handling processes of the product were identified.

Colour/Granulometry attributes

Honey colour measurements were performed according to IRAM 15941-2 (1997) using HI 96785C HANNA colorimeter (Hanna Instruments Inc., Woonsocket, Rhode Island, USA). In the case of crystallized honeys, samples were melted at 55 ± 2 °C in thermostatic bath until complete crystals dissolution and dissolved air eliminated, as indicated in the IRAM standard protocol. Colour of liquid honey was measured and results were expressed in Pfund-scale (Fell, 1978). Three replicate analyses were done for each sample.

Granulometry appearance is caused by formation of sugar crystals in honey caused by the separation of glucose in solid form. The rate, shape, size and density of the crystallization nuclei vary with honey composition and room temperature. Granulometry and crystal size were evaluated using three different standards (icing sugar glucose syrup solution and white and brown sugar solutions) and analysis were performed on a structured 12-point scale.

Statistical Analysis

Multiple comparisons test was performed using InfoStat program. Fisher's LSD (Least Significant Difference) test was used to compare means of t levels of a factor, after reject-

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ing the Null Hypothesis of Equality of Means by ANOVA technique. This test was applied to compare both, different families of odours and intensities of flavour. Consistency Tables methodology was used to analyze if differences in colour attributes between samples collected from each province or region, for different years were significant, taking as hypothesis that there is an association between colour attributes, province and year of collection.

Results

Flavour/Odour/Granulometry

The flavour results showed average values for sweet intensity of 6.25, 5.69 and 5.74 for honeys evaluated from the Provinces of Buenos Aires, Catamarca and Misiones, respectively. For acid intensity, the average values were 3.14, 3.13 and 3.50, while for bitter intensity, the average values obtained were 1.08, 1.38 and 2.09, respectively (Table 1).

Regarding odour intensity, honeys from the province of Misiones exhibited a more intense smell compared to those from the provinces of Catamarca and Buenos Aires, regardless of the year of study ($\alpha = 0.05$; $p < 0.001$). As for the granulometry of the honeys, it was observed that the three provinces studied did not show significant differences, regardless of the year of harvest ($\alpha = 0.05$; $p > 0.005$) (Table 1).

Colour

To examine the relationship between the colour of honey and its geographical origin in each year of the study, a statistical analysis of the contingency table was conducted. Based on the data, it can be concluded that the year of harvest does not significantly affect the colour of honey ($p > 0.05$) (Table 2). A similar analysis was performed to determine whether there are significant differences in the frequency of honey colours among the three provinces under study. It can be inferred that the province of origin significantly influences the colour of the honey ($p < 0.0001$) (Table 3). Light-coloured honeys (water white, white and extra light amber) are characteristic of Buenos Aires province, meanwhile dark coloured ones (dark amber, amber and light amber) are predominant in Catamarca and Misiones provinces (Figure 1).

Odour families/subfamilies

Characterization of honeys by odour families can be observed in Table 4, which presents the percentage of response to different subfamilies for each odour family, categorized by province and harvest year of the study. In Buenos Aires honeys, the warm family has a more intense subfamily subtle note (average 46%), while in Catamarca honeys, the fruit family exhibits a subfamily dry note (average 53%), and in Misiones honeys, the fresh family displays a subfamily refreshing note (average 67%) (Table 4). The sensory perception of family/subfamily notes per harvest for each province (Figure 2 a, b and c) is consistent with Table 4, indicating that the botanical characteristics of each region play a significant role in shaping the perceived smells in the honeys.

The statistical analysis of the results showed significant differences in some honey odour families (warm and fruit) between the provinces of Buenos Aires and Misiones. Catamarca province present significant differences in aromatic family odour compared to the other provinces studied (Table 5).

Discussion

Organoleptic characterization was conducted on honeys from three Argentinian provinces. No differences in colour, taste, and aroma intensity were found for each province throughout the years of the study. However, significant differences in honey colour and some family odour were observed between the provinces, indicating consistent and characteristic floral composition over time, re-

Table 1: Values for flavour intensity, odour and granulometry by province and harvest year.

Origin	Year	Flavour intensity			Odour	Granulometry
		Sweet	Acid	Bitter		
		$\bar{x} \pm SD$	$\bar{x} \pm SD$	$\bar{x} \pm SD$	$\bar{x} \pm SD$	$\bar{x} \pm SD$
Buenos Aires	2015	6.05 ± 1.73^a	2.73 ± 3.47^a	0.35 ± 1.02^a	5.17 ± 1.96^a	4.23 ± 2.30^a
Buenos Aires	2016	6.43 ± 2.65^a	3.28 ± 2.92^a	1.47 ± 2.30^a	4.72 ± 2.18^a	4.64 ± 2.76^a
Buenos Aires	2017	6.27 ± 2.30^a	3.41 ± 3.00^a	1.43 ± 2.46^a	4.66 ± 1.96^a	4.29 ± 2.64^a
Catamarca	2015	6.12 ± 1.79^a	3.58 ± 3.75^a	0.63 ± 1.54^a	5.73 ± 2.14^a	3.42 ± 1.76^a
Catamarca	2016	5.49 ± 2.63^a	2.70 ± 2.59^a	1.72 ± 2.34^a	4.73 ± 2.31^a	3.37 ± 2.52^a
Catamarca	2017	5.46 ± 2.12^a	$3.10 \pm 3.13a$	1.79 ± 2.78^a	5.59 ± 2.21^a	3.83 ± 2.56^a
Misiones	2015	5.74 ± 1.97^a	3.64 ± 4.06^a	1.16 ± 2.12^a	6.37 ± 2.02^b	2.85 ± 1.78^a
Misiones	2016	6.08 ± 2.69^a	3.37 ± 2.97^a	2.04 ± 2.70^a	6.34 ± 2.20^b	3.99 ± 3.10^a
Misiones	2017	5.41 ± 2.28^a	3.48 ± 3.17^a	3.07 ± 3.47^a	6.77 ± 2.06^b	5.92 ± 3.12^a

Different letters correspond to significant differences ($\alpha = 0.05$; $p < 0.001$)

Table 2: Relative frequency of each colour (expressed as percentage) for each harvest year.

International Scale	Harvest year			
	2015	2016	2017	Total
water white	3.85	0.00	0.00	1.18
white	23.08	14.29	12.90	16.47
extra-light amber	11.54	25.00	25.81	21.18
light amber	19.23	35.71	38.71	31.76
amber	23.08	21.43	12.90	18.82
dark amber	19.23	3.57	9.68	10.59
Total	100.00	100.00	100.00	100.00
Statistic		Value	df	p
Pearson Chi Square		10.91	10	0.3646
MV-G2 Chi Square		11.47	10	0.3218
Cramer's conting. coef.		0.21		

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Table 3: Relative frequency of each colour (expressed as percentage) for each province.

International Scale	Provinces			
	Buenos Aires	Catamarca	Misiones	Total
water white	3.23	0.00	0.00	1.18
white	35.48	7.69	3.57	16.47
extra light amber	48.39	11.54	0.00	21.18
light amber	12.90	30.77	53.57	31.76
amber	0.00	34.62	25.00	18.82
dark amber	0.00	15.38	17.86	10.59
Total	100.00	100.00	100.00	100.00
Statistic		Value	df	*p*
Pearson Chi Square		53.26	10	< 0.0001
MV-G2 Chi Square		65.06	10	< 0.0001
Cramer's conting. coef.		0.46		
Pearson's conting. coef.		0.62		

Table 4: Percentage of response of the different families/subfamilies of odour notes by harvest year and province.

Family	Scents/ Subfamily	Buenos Aires province (% response)			Catamarca province (% response)			Misiones province (% response)		
		2015	2016	2017	2015	2016	2017	2015	2016	2017
Warm	Subtle	48.94	42.67	45.24	24.00	27.69	25.49	40.08	22.68	38.91
	Candy	26.52	22.22	24.38	32.72	22.48	23.75	27.78	19.59	15.26
	Lactic	18.90	18.13	11.10	16.05	15.67	17.10	12.63	10.10	6.69
	Tosted	1.39	0.79	0.00	6.17	12.90	12.07	12.75	11.48	7.66
	Burnt	1.58	0.79	0.00	16.22	9.11	1.77	1.00	3.70	1.14
Aromatic	Wood	22.78	49.08	50.28	30.88	44.05	27.29	6.71	17.82	25.33
	Resin	38.45	14.81	9.26	16.83	27.62	12.69	31.25	37.42	19.63
	Spicy	23.03	2.78	14.26	39.38	20.39	38.41	55.75	33.54	29.20
Fruit	Fresh	34.17	23.70	9.50	19.00	9.00	16.17	14.38	27.46	16.45
	Cítric	15.81	20.92	25.67	7.67	18.17	31.67	11.13	28.81	11.92
	Dry	46.15	35.00	34.83	**69.33**	**45.83**	**43.00**	64.38	33.26	46.70
Floral	Subtle	43.44	38.94	55.72	31.88	20.00	29.00	32.29	40.48	1.30
	Intense	28.17	34.89	29.11	13.88	26.66	44.33	33.34	37.82	65.32
Vegetal	Green	11.08	20.37	35.00	8.33	37.33	35.00	46.88	27.78	31.82
	Dry	15.33	20.37	40.00	50.00	10.67	25.00	25.00	16.67	0.00
Fresh	Refreshing	45.83	0.00	50.30	50.00	40.00	84.54	**75.00**	**85.19**	**41.13**
Chemical	Stinging	33.13	0.00	10.00	22.17	25.00	10.00	25.00	41.74	49.55
	Petrochemical	6.18	0.00	0.00	11.17	20.00	0.00	0.00	22.22	4.55
Degraded	Animal	29.53	29.63	2.50	12.50	10.00	20.00	32.50	33.96	25.60
	Proteic	9.10	47.22	22.50	23.33	20.00	6.67	12.50	13.68	16.21
	Sulfur	13.58	9.26	5.00	10.00	0.00	3.33	27.50	3.70	7.88

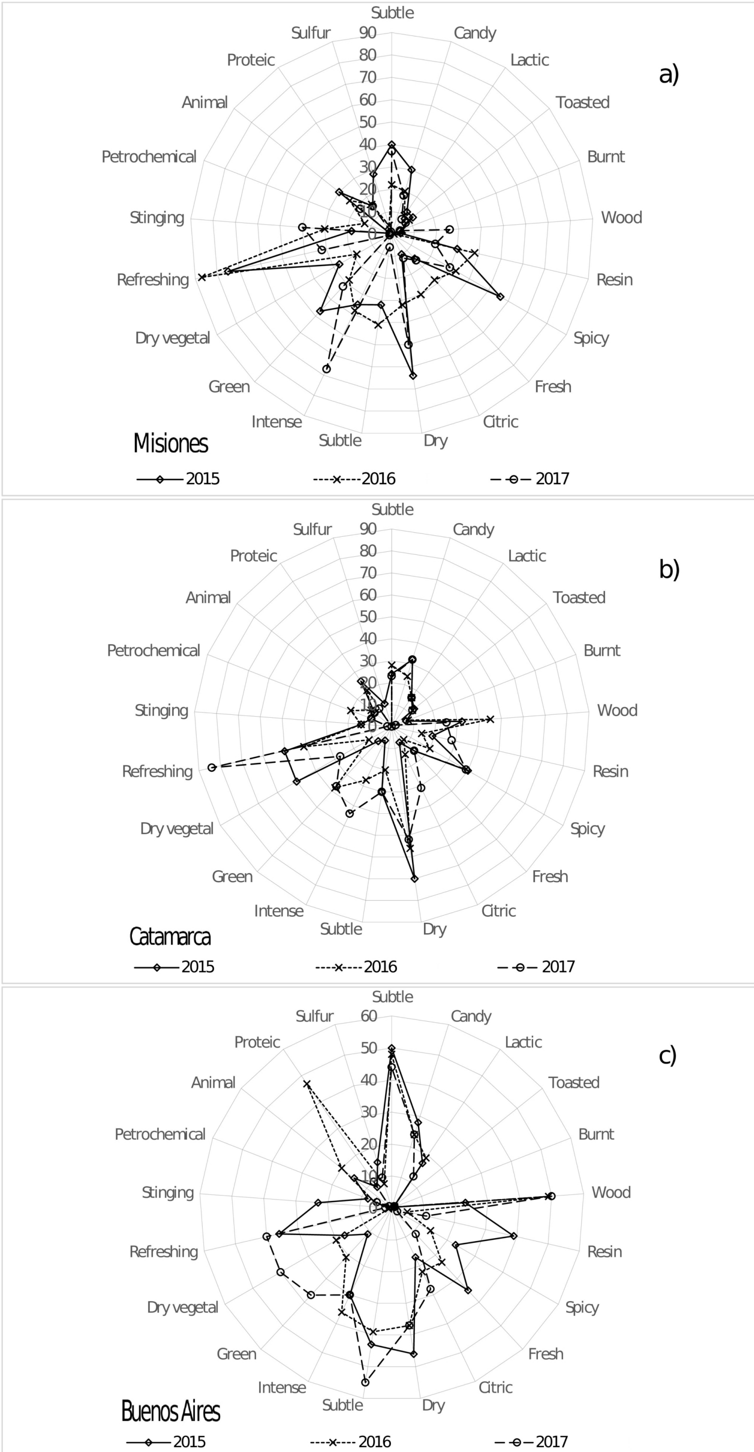

Figure 2: Sensory profile of honeys by harvest year and by province evaluated a) Misiones, b) Catamarca and c) Buenos Aires.

gardless of whether they originated from one or more phytogeographic regions.

Honeys from Misiones and Buenos Aires provinces are distinguishable basically because their surface is predominantly occupied by a common phytogeographic region

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Table 5: Mean percentage of response for each family odour for each province.

Family	Response (%)		
	Buenos Aires	Catamarca	Misiones
Warm	17.51^{a**}	17.55^{ab*}	15.43^{b**}
Aromatic	24.97^{a**}	28.62^{b**}	28.52^{ab*}
Fruit	27.31^{a**}	28.87^{ab*}	28.27^{b**}
Floral	38.38^{a*}	27.63^{a*}	35.09^{a*}
Vegetable	23.69^{a*}	27.72^{a*}	24.69^{a*}
Fresh	32.04^{a*}	58.18^{a*}	67.11^{a*}
Chemical	8.22^{a*}	14.72^{a*}	23.84^{a*}
Degraded	18.70^{a*}	11.76^{a*}	13.58^{a*}

Different letters correspond to significant differences ($\alpha = 0.05$; $p < 0.001$)

(PP Pampeana). While only half of Catamarca province is engaged in intensive honey production, it produces a diverse range of honeys, some of which share sensory characteristics with the honeys from the other two provinces, making them undifferentiable.

Nevertheless, sensory analysis allows for differentiation between phytogeographic regions primarily due to their distinct flora. The influence of the flora and the pedoclimatic conditions of each phytogeographical region on the sensorial properties of honey allowed its characterization (Poliero et al., 2022).

Sensory characteristics play an essential role in studies of food preference and aversion among human consumers. Some consumers may prefer dark-coloured honeys with intense aroma and refreshing scent notes (Fresh family), such as those produced in Misiones province. On the other hand, others may prefer light-coloured honeys with a mild odour and subtle scent notes (Warm family), like those from the Pampeana ecoregion (Buenos Aires).

In this context, a Protected Designation of Origin (PDO) could be assigned to honeys from specific geopolitical origins, particularly when a single phytogeographic region covers a significant portion of the territory (e.g., Misiones). For Catamarca province, which encompasses more than one phytogeographic region, a broader PDO area could be considered (e.g., honey from Catamarca and Yungas region) to define its characteristics. Typifying honeys from each studied phytogeographical region would provide them with added value and access to new markets, as typified honey has a higher commercial value than standard quality honey. Notably, there is a growing global demand for differentiated products, highlighting the importance of having typified honeys. Thus, this study makes a significant contribution to the characterization of honeys from Argentina.

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