DOI: 10.1002/jsfa.2105

Unifloral honeys of the province of Buenos Aires, Argentine

Néstor H Malacalza,[1] Marta A Caccavari,[2] Guillermina Fagúndez[2] and Cecilia E Lupano[3]*

[1]*Ministerio de Agricultura, Ganadería y Alimentación. Laboratorio de Calidad de Miel, 13 y 532, 1900 La Plata, Argentina*
[2]*CIC y TTP, CONICET, Matieri y España, 3105 Diamante, Entre Ríos, Argentina*
[3]*Centro de Investigación y Desarrollo en Criotecnología de Alimentos (CIDCA), Facultad de Ciencias Exactas, UNLP-CONICET, 47 y 116, 1900 La Plata, Argentina*

Abstract: Samples of 63 unifloral honeys of the province of Buenos Aires, Argentina, from *Eucalyptus* spp, *Lotus* spp, *Helianthus annuus, Melilotus albus*, Brassicaceae, clovers other than *Lotus* and *Melilotus*, and *Sagittaria montevidensis*, were obtained by cold extraction at the laboratory. The frequencies of occurrence of pollen types, and the moisture, hydroxymethylfurfural, ash, acidity and proline contents were determined. Electrical conductivity, pH and colour were also analysed. Honey presented a high percentage (about 40%) of unifloral honey. The most frequent unifloral honeys were from *Eucalyptus* spp, *Lotus* spp and *Helianthus annuus*. Samples had a low pollen diversity with six to 19 pollen types, the most important nectariferous taxa being those that characterized the unifloral honeys. All samples presented moisture, hydroxymethylfurfural, ash and free acidity contents according to international standards. The colour of the honey was from water white to light amber, and all samples had a very low ash content. Significant differences at the 5% level in the hydroxymethylfurfural content, electrical conductivity, colour and proline content were observed among honeys from different floral origins. However, a high variability between samples from the same floral origin was observed, indicating that other factors such as accompanying pollen and geographical origin affect the physicochemical characteristics of honey.
© 2005 Society of Chemical Industry

Keywords: unifloral honey; province of Buenos Aires; Argentine honey; honey characterization

INTRODUCTION

Honey is a nutritious food, with economic importance for many countries worldwide.[1] The botanical origin of a honey determines to a great extent its physicochemical and organoleptic properties. Unifloral honeys of a particular origin may be greatly appreciated by the consumer and, thus, the characterization of unifloral honeys would be of particular interest to the beekeeper.[2]

Argentina is the third largest producer of honey, and the largest honey exporter. Buenos Aires is the largest honey-producing province in Argentina, accounting for more than 50% of Argentina's honey production. This province is situated in the middle-east of the country, in the zone called the 'wet pampa', having a vegetation with thistle, clover, eucalyptus, cruciferae and sunflower.[3,4] Honey produced in this province is labelled 'multifloral prairie honey', even when a high percentage of it is unifloral honey.

Several studies have been performed on unifloral honey from different countries,[1,2,5–14] but very little information has been found concerning the physicochemical characteristics of argentinian honeys. Palynological analysis is the international method used to characterize the botanical origin of honeys.[15] The general criterion used to characterize unifloral honey takes into account the presence of a single dominant pollen type in quantities greater than 45% of the total pollen content.[15] In the case of *Eucalyptus*, because of its over-represented pollen, the percentage value considered for unifloral honeys is 70%.[15] Clover honey comprises several legume pollens, such as *Lotus* spp, *Melilotus* spp, *Trifolium* spp and *Medicago sativa*.

In this study, 63 unifloral honeys of the province of Buenos Aires, Argentina, were characterized through pollen and physicochemical analysis.

EXPERIMENTAL

Honey was collected from different zones of the province of Buenos Aires. Honey samples were obtained by cold extraction at the laboratory, in order

* Correspondence to: Cecilia E Lupano, Centro de Investigación y Desarrollo en Criotecnología de Alimentos (CIDCA), Facultad de Ciencias Exactas, UNLP-CONICET, 47 y 116, 1900 La Plata, Argentina
E-mail: cel@quimica.unlp.edu.ar
Contract/grant sponsor: Agencia Nacional de Promoción Científica y Tecnológica; contract/grant number: BID 1201/OC-AR, PICT 09-04423
(*Received 9 June 2004; revised version received 27 August 2004; accepted 18 October 2004*)
Published online 21 February 2005

to ensure that samples were not modified during the extraction procedures, and were stored at −20 °C until analysed. Unifloral honeys were selected from 148 honey samples by pollen analysis, which was performed according to the method of Louveaux *et al*.[15]

Methods recommended by Argentinian regulations (Normas IRAM), based on the analytical procedures of Codex Alimentarius, AOAC and DIN, were used to determine colour, pH and electrical conductivity, and analyse moisture, ash, total, free and lactonic acidity, hydroxymethylfurfural (HMF) and proline content. Moisture was determined with an Abbe refractometer reading at 20 °C, obtaining the corresponding value of moisture from the Chatway Table.[16] Ash content was measured by calcination until constant weight in a furnace at 550 °C.[17] HMF was measured according to the method of White, adopted by Normas IRAM.[18,19] Colour was measured according to the Pfund classifier, adopted by Normas IRAM.[20] In this method, homogeneous liquid honey, without air bubbles, is put into the Pfund colorimeter, and the colour is visually compared with standards. Colour grades of honey based on Pfund readings are (average scale reading): ⩽8 mm, water white; 9–16, extra white; 17–34, white; 35–50, extra light amber; 51–85, light amber; 86–114, amber; >114, dark.[20] All assays were performed in replicate, except proline content, which was determined in triplicate.

The average, maximum, minimum and standard deviations of physicochemical data were calculated for each unifloral honey. An analysis of variance of the data was performed in order to estimate the differences between unifloral honeys. *Sagittaria* honey was not considered in this analysis because there was only one sample.

RESULTS AND DISCUSSION

Pollen analysis

In this study, 63 of 148 honey samples were unifloral. The most frequent unifloral honeys were from *Eucalyptus* spp (23 samples) and *Lotus* spp (21 samples). Unifloral honeys of *Melilotus albus* (three samples), Brassicaceae (3 samples), *Helianthus annuus* (nine samples), *Sagittaria montevidensis* (one sample) and clover (three samples) were also found. In this study clover honeys included several legume pollens other than *Lotus* and *Melilotus*, which were considered separately. Tables 1 and 2 show the frequencies of occurrence of pollen types in unifloral honeys.

The unifloral honeys analysed were characterized by low pollen diversity, with six to 19 pollen types. Seventy pollen types were recognized, but generally *Lotus, Eucalyptus* and *Helianthus* (sunflower) were present as secondary pollen. Other frequent pollen types were Brassicaceae, *Cirsium vulgare, Centaurea* sp *and Mentha pulegium*.

An overall consideration of Buenos Aires honeys shows that the most important nectariferous taxa are those that characterize unifloral honeys. Polliniferous taxa (Gramineae, Cyperaceae) were very scarce. This is in accordance with results reported by Tellería,[21] who identified 62 morphological types in 30 samples of honey from the province of Buenos Aires, 53 belonging to nectar plants and nine to pollen plants. In several samples, pollen of native taxa was present in a minor percentage, representing the origin [*Polygonum* spp, *Sagitaria montevidensis* in the northeast (Paraná River area), *Schinus* sp, *Prosopis* sp, Rhamnaceae in the southwest (Monte area), *Acacia bonariensis* in the river area and Mentha in the centre and north of the province]. Andrada *et al*[22] analysed 58 honey samples from the province of Buenos Aires and found that the predominating pollen was *Eucalyptus* spp, whereas pollen from native species was rare.

The *Lotus* honeys analysed were mostly from the northeast regions of the Buenos Aires province, the *Helianthus* honeys were mostly from the centre and southern regions, Brassicaceae honeys were from south regions, and *Sagittaria* honey was from the Paraná River region. The *Eucalyptus, Melilotus* and clover honeys were from different regions. Tellería[21,23,24] found unifloral honeys from *Lotus tenuis*, eucalyptus, *Trifolium repens* L, and abundant pollen from Cruciferae, *Echium plantagineum, Mentha* sp, *Conium* sp and *Ammi* sp in the province of Buenos Aires.

Moisture content

The moisture content is the only composition criterion which, as part of the Honey Standard, has to be fulfilled in world honey trade. Honey having a high water content is more likely to ferment. A maximum of 210 g kg^{-1} honey was suggested as a standard in 1999.[25] According to Mercosur standards, the moisture content in honey must be <200 g kg^{-1}.[26]

The average of the moisture content of unifloral honeys analysed in this study was <180 g kg^{-1}, except clovers and *Sagittaria* honeys, which presented an average value of moisture content of 181 g kg^{-1}. Sunflower honey (nine samples) presented two samples with moisture contents a little higher than 180 g kg^{-1}, whereas six samples from the 23 samples of eucalyptus honey, and four of the 27 samples of clover analysed (including *Lotus* and *Melilotus*), had a moisture content higher than 180 g kg^{-1} (Table 3). All honeys analysed presented moisture contents of ⩽200 g kg^{-1}. No differences at the 5% level were detected in the moisture content among different unifloral honeys.

Hydroxymethylfurfural

The HMF content in Argentine is required to be ⩽40 mg kg^{-1}, in accordance with international standards.[25] All samples analysed in this work presented HMF according to these regulations (Table 3). The HMF content is an indicator of honey freshness and overheating. In fresh honey there is practically no HMF, but it increases upon storage,

Table 1. Pollen types and their frequency in *Eucalyptus, Lotus* and *Helianthus* honeys D, predominant pollen (>45%); S, secondary pollen (16–45%); M, minor important pollen (3–15%); T, minor pollen (1–3%); +, sporadic pollen (<1%)

		Eucalyptus honeys					*Lotus* honeys					*Helianthus* honeys				
Family	Pollen type	D	S	M	T	+	D	S	M	T	+	D	S	M	T	+
Alismataceae	*Sagittaria montevidensis*										2			1	1	
Anacardiaceae	*Schinus* sp					1										
Apiaceae	*Ammi* spp				1	5			1	1	8					5
	Eryngium spp					3					4					2
Asteraceae	*Ambrosia* sp										1					
	Astereae					4					2					2
	Baccharis sp					1				1	4					2
	Carduus spp					5			5		4				3	1
	Centaurea spp			1	1	12				1	5			2	1	1
	Cichorium intybus					1				1	4					
	Cirsium vulgare			1	3	10			2	2	4			1	1	1
	Heliantheae										1					
	Helianthus annuus			6	10	4			4	2	8	9				
	Picris sp					4			2		1					1
	t *Plagiocheilus tanacetoides*													2		
	t *Solidago chilensis*														1	
	t *Sonchus*										1				1	1
	t *Xanthium*					1					4					4
Boraginaceae	*Echium plantagineum*			1		3			1		5			1		
Brassicaceae				4	3	6				3	8		1	2	1	3
Capparidaceae	t *Cleome*										3					
Cyperaceae	*Cyperus* sp					1					1					
Euphorbiaceae	*Sapium haematospermum*										1					
Fabaceae	*Acacia bonariensis*					2					2					
	Adesmia spp				1	6				1	2		1			1
	Glycine max					1				1	1					1
	Lotus spp		4	7	3	4	21						1	1	2	1
	Medicago sativa				1				1		3					
	t *Melilotus albus*			1	7	9		3	6	3	6			4	2	1
	Papilionoideae					1					1					1
	Parkinsonia aculeata					2					2					
	Prosopis spp					2					1					
	Trifolium pratense				1	4					6					1
	Trifolium repens					1				1	1					
	Trifolium sp					1				1						2
	Vigna luteola													1	1	
Geraniaceae	t *Erodium*															1
Lamiaceae	*Hyptis* sp					1										1
	Mentha puligeum					5			5	3	7					2
	t *Teucrium*					1					2					2
Liliaceae						1							1			
Malvaceae						1									1	21
Myrtaceae	*Eucalyptus* spp	23						9	5	3	5		1	1	5	1
Onagraceas	*Ludwigia* sp										1					1
Oleaceae	*Ligustrum lucidum*				1	6				1	4					1
Papaveraceae	t *Argemone subfusiformis*										1					
Poaceae											2					
	Zea mays					2					1					1
Polygonaceae	*Polygonum* sp														1	1
Rhamnaceae					1	1					1					
Rosaceae	t *Prunus*										1					1
Scrophulariaceae	*Gerardia communis*										2					
Solanaceae	*Cestrum parqui*				1	1				1						
	Lycium sp															1
	Petunia sp					2										
	Solanum sp					1					3			1		1

(*continued overleaf*)

Table 1. Continued

Family	Pollen type	*Eucalyptus* honeys					*Lotus* honeys					*Helianthus* honeys				
		D	S	M	T	+	D	S	M	T	+	D	S	M	T	+
Ulmaceae	t *Celtis*										2					2
Urticaceae						2					2					
Verbenaceae	*Phyla* sp					1				4	6					1
	Verbena sp					5					1					2

Table 2. Pollen types and their frequency in Brassicaceae, *Melilotus*, clover and *Sagittaria* honeys D, predominant pollen (>45%); S, secondary pollen (16–45%); M, minor important pollen (3–15%); T, minor pollen (1–3%); +, sporadic pollen (<1%)

Family	Pollen type	Brassicaceae honey					*Melilotus* honey					Clover honey					*Sagittaria* honey				
		D	S	M	T	+	D	S	M	T	+	D	S	M	T	+	D	S	M	T	+
Alismataceae	*Sagittaria montevidensis*														1	1	1				
Amar.-Quenopod.																1					
Anacardiaceae	*Schinus* sp				1						1					1					
Apiaceae	*Ammi* spp										1				1						
	Eryngium spp					1															
Asteraceae	*Artemisia* sp															1					
	Astereae															2					
	Carduus spp										1					1					
	Centaurea spp		1		2					1						1					
	Cichorium intybus					1					1					2					
	Cirsium vulgare					2				1	2				1	2					
	t *Gymnocoronis spilanthoides*																			1	
	Helianthus annuus			1	1					1	1			1	1	1					
	t *Plagiocheilus tanacetoides*																			1	
	t *Tessaria integrifolia*															1			1		
Bignoniaceae																1					
Boraginaceae	*Echium plantagineum*															1					
Brassicaceae		3								2	1			1	1	1				1	
Euphorbiaceae	t *Manihot flabellifolia*										1										
Fabaceae	*Adesmia* sp				1						1										
	t *Desmodium*															1					
	Glycine max									1				1	2						
	Lotus spp					1			1	1			2	1							
	Medicago sativa									1					1						
	Melilotus albus			1		1	3						3								
	Papilionoideae																				1
	Prosopis spp			1		2									1						
	Trifolium pratense					2			1	1				1	2						
	Trifolium repens										1										
	Trifolium sp			1							1					1					
	Vigna luteola															1			1		
Lamiaceae	*Mentha puligeum*								1						1						
	Scutellaria racemosa										1					1					
	t *Teucrium*															1					
Linaceae	t *Linum*															1					
Myrtaceae	*Eucalyptus* spp		1	1	1			1	1	1			2	1					1		
Oleaceae	*Ligustrum lucidum*										1				1	1					
Poaceae											1					1					
Polygonaceae	*Polygonum* sp				1														1		
Rhamnaceae					1	1										1					
Salicaceae	t *Salix*																				1
Scrophulariaceae	*Gerardia communis*										1										
Solanaceae	*Cestrum parqui*										1					1					
	Solanum sp					2					1										
Ulmaceae	t *Celtis*										1				1	1					1
Verbenaceae	*Verbena* sp										1				1	1					

Table 3. Physicochemical characterisation and composition of honey

Honey	Number of samples		Unifloral pollen (%)	Moisture ($g\,kg^{-1}$)	HMF ($mg\,kg^{-1}$)	Ash ($g\,kg^{-1}$)	Electrical conductivity ($10^{-4}\,S\,cm^{-1}$)
Lotus	21	Average	69.9	164	3.5	0.72	0.22
		Maximum	98.3	174	8.3	1.34	0.34
		Minimum	49.2	148	1.4	0.04	0.12
		SD	12.8	8	1.7	0.41	0.06
Melilotus	3	Average	60.6	164	7.5	0.87	0.27
		Maximum	83.7	183	17.9	1.45	0.39
		Minimum	48.4	154	1.6	0.44	0.18
		SD	20.0	16	9.0	0.52	0.11
Brassicaceae	3	Average	69.5	164	5.6	0.99	0.24
		Maximum	90.4	173	6.9	1.55	0.39
		Minimum	53.0	148	3.5	0.50	0.16
		SD	19.1	12	1.7	0.48	0.11
Helianthus	9	Average	60.6	170	2.7	0.93	0.32
		Maximum	80.0	192	6.9	1.56	0.40
		minimum	50.0	160	0.4	0.15	0.21
		SD	7.7	10	2.2	0.50	0.07
Eucalyptus	23	Average	85.8	166	2.9	0.82	0.28
		Maximum	99.0	200	6.3	1.53	0.46
		minimum	70.6	144	0.7	0.29	0.16
		SD	9.9	16	1.5	0.31	0.10
Clover	3	Average	57.5	181	6.7	0.70	0.26
		Maximum	70.0	193	21.4	1.51	0.32
		minimum	48.0	167	1.4	0.17	0.22
		SD	11.3	13	8.4	0.71	0.06
Sagittaria	1		48.7	181	0.9	0.76	0.28

depending on the pH of the honey and on the storage temperature.[25]

In the present work, honey was obtained by cold extraction, and no heating treatments were used. Thus, low values of HMF were found in all samples, as expected. The analysis of variance showed that the are significant differences at the 5% level between honeys of different floral origins.

Electrical conductivity and ash content

Conductivity is a good criterion of the botanical origin of honey, and today it is determined in routine honey control instead of the ash content.[25] Table 3 shows the electrical conductivity and the ash content of different unifloral honeys. Ash content and electrical conductivity of eucalyptus honeys (Table 3) were lower than values reported by Martínez Gomez *et al*,[8] and by Serra Bonvehi and Cañas Lloria,[7] who found values of ash content between 0.8 and 3.1 $g\,kg^{-1}$ in eucalyptus honeys, with an average value of 1.7 $g\,kg^{-1}$ and a standard deviation of 0.5 $g\,kg^{-1}$. Ash values must be $<6\,g\,kg^{-1}$ in floral honeys.[25,26] All samples of the present study had very low ash values, the highest value being 1.56 $g\,kg^{-1}$.

The analysis of variance showed that there are significant differences at the 5% level in the electrical conductivity among honeys from different floral origins, but no differences were found in the ash content.

A linear relationship was reported between the ash content and the electrical conductivity:[25]

$$C = 0.14 + 0.174A \quad (1)$$

where C is the electrical conductivity in $mS\,cm^{-1}$ and A the ash content in $g\,kg^{-1}$ honey.

The electrical conductivity as a function of ash content for all unifloral honeys studied in this work showed a value of C when A was zero of 0.17, a little higher than that presented in equation (1), whereas the slope was 0.116, which was lower than that in equation (1). It must be taken into account that only the lower part of the curve is represented in this work, because the honeys analysed presented very low values of ash and electrical conductivity.

Acidity

Acidity is an important quality criteria. Honey fermentation causes an increase in acidity, although there is a considerable natural variation. The Codex draft fixed a maximum of 50 $meq\,kg^{-1}$.[25] Free acidity was similar in all unifloral honeys (Table 4), with averages between 16.7 and 22.8 $meq\,kg^{-1}$. The highest values were found in *Lotus* spp honeys, with values ranging from 10.0 to 30.3 $meq\,kg^{-1}$. Values of free acidity were similar to those reported by Mendes *et al* in Portuguese honey,[27] but higher than those obtained by Sporns *et al* in Alberta honey.[28] On the other hand, Sanz *et al*[12] found in La Rioja honeys higher values of

Table 4. Physicochemical characterisation and composition of honey

Honey		PH	Free acidity (meq kg^{-1})	Lactonic acidity (meq kg^{-1})	Total acidity (meq kg^{-1})	Colour (mm Pfund)	Proline (mg kg^{-1})
Lotus	Average	3.6	16.7	13.5	30.9	11.2	479
	Maximum	4.7	30.3	38.5	56.6	56.3	930
	Minimum	3.3	10.0	3.4	14.7	1.0	217
	SD	0.3	6.5	9.1	11.3	15.1	204
Melilotus	Average	3.6	18.8	21.8	40.6	30.1	682
	Maximum	3.9	27.6	36.7	64.3	46.6	1075
	Minimum	3.4	12.7	10.9	27.1	1.0	279
	SD	0.2	7.8	13.4	20.6	25.3	398
Brassicaceae	Average	3.5	18.8	9.0	27.8	24.1	518
	Maximum	3.7	23.9	13.4	37.3	66.0	716
	Minimum	3.2	13.0	5.2	18.2	2.1	379
	SD	0.2	4.9	3.8	8.6	32.5	176
Helianthus	Average	3.7	17.3	11.5	28.8	33.1	373
	Maximum	4.1	22.7	16.8	39.3	61.0	569
	Minimum	3.5	12.7	7.6	22.4	21.5	299
	SD	0.2	3.5	3.3	5.4	13.9	82
Eucalyptus	Average	3.6	18.2	16.8	35.1	25.4	498
	Maximum	3.8	22.9	37.1	59.9	55.3	744
	Minimum	3.4	13.3	5.7	23.0	1.0	280
	SD	0.2	2.9	11.1	12.0	17.4	105
Clover	Average	3.5	22.8	21.0	43.9	28.2	724
	Maximum	3.7	25.9	37.0	63.0	61.0	1096
	Minimum	3.4	18.8	12.3	31.1	7.1	502
	SD	0.1	3.7	13.9	16.9	28.8	324
Sagittaria		3.9	22.2	18.6	40.8	74.7	753

free acidity and lower values of lactonic acidity than those presented in this work.

The pH values obtained in this work were between 3.2 and 4.7, *Lotus* spp and sunflower honeys presenting the highest values (Table 4). These values were lower than pH values reported by other authors in La Rioja and Slovenia honey.[12,29]

No significant differences were found in the acidity or pH values between honeys of different floral origins.

Colour

The colour of honeys, at a thickness of about 30 mm, ranges from a pale yellow through amber to deep red or even black, depending on the floral source and composition. In general, lighter colours are associated with delicate flavours and darker colours with strong flavours and less attractive appearance. Colour is thus a factor in the grading and marketing of honey.[30]

For many years the standard reference in USA has been the Pfund classifier, and this standard has also been adopted in many other countries, including Argentina. According to this classification, honeys studied in the present work are from water white to light amber (Table 4), the averages of different unifloral honeys being extra white or white. As data presented in Table 3 do not permit appreciation of the variability between samples of the same floral origin, the number of samples that presented the same colour grade in each unifloral honey is shown in Fig 1. Results show that most *Lotus* spp honey was water white, whereas most sunflower honey was white. *Eucalyptus* spp honey presented a colour from water white to light amber. Because of the low number of samples of *Melilotus albus*, Brassicaceae and clover honey, it was not possible to observe a tendency in these samples. The analysis of variance showed that there were significant differences ($p < 0.05$) in the colour of honey of different floral origin.

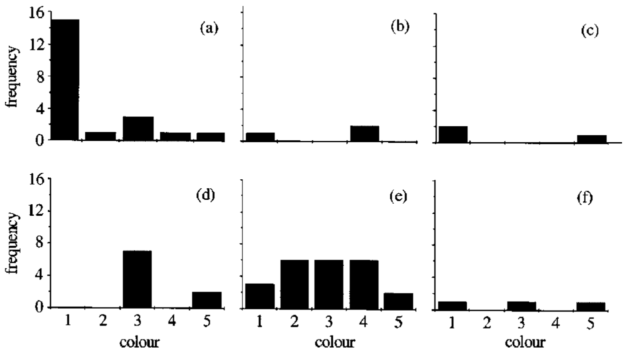

Figure 1. Number of samples of unifloral honeys of the province of Buenos Aires that present the same colour grade. 1, Water white; 2, extra white; 3, white; 4, extra light amber; 5, light amber. (a) *Lotus* sp; (b) *Melilotus albus*; (c) Brassicaceae; (d) *Helianthus annus*; (e) *Eucalyptus* sp; (f) clover other than *Lotus* sp and *Melilotus albus*.

The colour of honey is in part determined by the ash content: in general, darker colours are associated with higher ash contents. Figure 2 shows the colour of different unifloral honeys as a function of their ash content. A linear fit of these two parameters showed a correlation coefficient of 0.61.

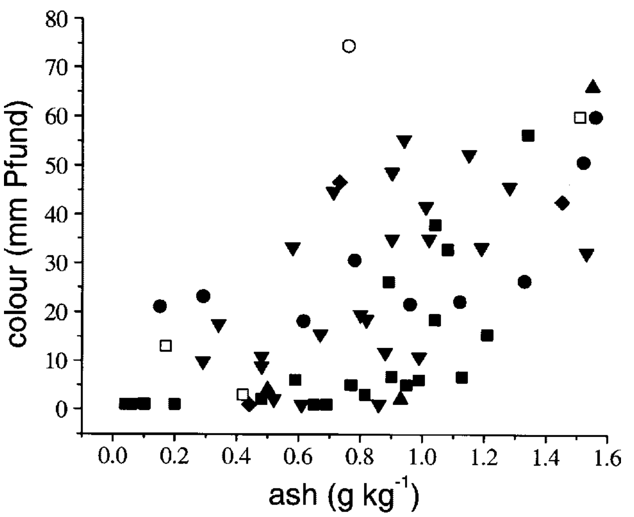

Figure 2. Colour as a function of ash content of unifloral honeys of the province of Buenos Aires. Honey: (■) *Lotus* sp; (♦) *Melilotus albus*; (▲) Brassicaceae; (●) *Helianthus annus*; (▼) *Eucalyptus* sp; (□) clover other than *Lotus* sp and *Melilotus albus*; (○) *Sagittaria montevidensis*.

Proline

The amount of this amino acid in honey can be supplemented by proline in nectar and pollen.[28] Table 4 shows the proline content of the honey samples analysed in the present study. Sunflower honey presented the lowest proline content, with values ranging from 299 to 569 mg kg^{-1}. The analysis of variance showed significant differences ($p < 0.05$) in the proline content between honey samples from different floral origins.

The proline contents of samples analysed in the present work were higher than those reported by Sporns *et al* in Alberta honey.[28] However, according to these authors, only 1% of 482 US honeys would have proline contents lower than 200 mg kg^{-1},[28] which agrees with results obtained in the present work, in which the lowest proline content was 217 mg kg^{-1}.

CONCLUSIONS

Honey from the province of Buenos Aires presented a high percentage (about 40%) of unifloral honey. The most frequent unifloral honeys were from *Eucalyptus* spp, *Lotus* spp and *Helianthus annuus*. Samples presented a low pollen diversity with six to 19 pollen types, the most important being nectariferous taxa that characterize the unifloral honeys.

The honey presented moisture, HMF, ash and free acidity contents according to international standards. The colour of honey varied from water white to light amber, and the honey had very low values of ash content and electrical conductivity.

Significant differences at the 5% level in the HMF content, electrical conductivity, colour and proline content were observed among honeys from different floral origins. However, a high variability between samples of the same floral origin was observed, indicating that other factors such as accompanying pollen and geographical origin would affect the physicochemical characteristics of honey.

ACKNOWLEDGEMENTS

This investigation was supported by grant from the Agencia Nacional de Promoción Científica y Tecnológica, BID 1201/OC-AR, PICT 09-04423. CE Lupano and MA Caccavari are members of the Researcher Career of the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET).

REFERENCES

1 Alissandrakis E, Daferera D, Tarantilis PA, Polissiou M and Harizanis PC, Ultrasound-assisted extraction of volatile compounds from citrus flowers and citrus honey. *Food Chem* **82**:575–582 (2003).
2 Seijo MC, Jato MV, Aira MJ and Iglesias I, Unifloral honeys of Galicia (north-west Spain). *J Apicult Res* **36**:133–139 (1997).
3 Cabrera AL and Zardini EM, *Manual de la flora de los alrededores de Buenos Aires*. ACME SACI Buenos Aires (1993).
4 Cabrera AL, Regiones fitogeográficas Argentinas, in *Enciclopedia Argentina de Agricultura y Jardinería*, Vol II. ACME SACI, Buenos Aires (1994).
5 Patetta A, Ferrazzi P and Manino A, Caratteristiche fisico-chimiche di mieli di "Robinia" (*Robinia pseudo acacia* L) piemontesi. *L'apicoltore moderno* **68**:144–149 (1977).
6 Piazza MG, Accorti M and Persano Oddo L, Indagine sulle caratteristiche chimico-fisiche dei mieli italiani di castagno e di melata. *Apicolt Mod* 77:47–51 (1986).
7 Serra Bonvehi J and Cañas Lloria S, Caratteristiche fisico-chimiche, composizione e spettro pollinico del miele di eucalipto (*Eucalyptus* spp) in Spagna. *Apicoltura* **4**:59–81 (1988).
8 Martinez Gomez ME, Guerra Hernández E, Montilla Gomez JY and Molins Marin JL, Physicochemical analysis of Spanish commercial *Eucalyptus* honeys. *J Apicult Res* **32**:121–126 (1993).
9 Papoff CM, Floris I, Lampis A and Chessa S. Caratteristiche chimico fisiche di alcuni mieli uniflorali della Sardegna. *L'Ape* **3**:4–8 (1995).
10 Serra Bonvehi J and Ventura Coll F, Characterization of citrus honey (*Citrus* spp) produced in Spain. *J Agric Food Chem* **43**:2053–2057 (1995).
11 Conte LS, Miorini M, Giomo A, Bertacco G and Zironi R, Evaluation of some fixed components for unifloral honey characterization. *J Agric Food Chem* **46**:1844–1849 (1998).
12 Sanz S, Pérez C, Herrera A, Juan T and Sanz M, La Rioja. Caracterización de mieles monoflorales. *Vida Apícola* **91**:36–45 (1998).
13 Ricciardelli D'Albore G, Verifica decennale sulla stabilità dello spettro pollinico nei mieli di Castagno (*Castanea sativa* Miller) e di Robinia (*Robinia pseudoacacia* L) della Provincia di Varese. *L'Ape* **2**:18–22 (1998).
14 Persano Oddo L, Festuccia N and Quaranta M, Il miele di rosmarino (*Rosmarinus officinalis* L) prodotto in Italia: caratteristiche melissopalinologiche e organolettiche. *L'Ape* **1**:6–20 (1998).
15 Louveaux J, Maurizio A and Vorwohl G, Methods of melissopalynology. *Bee World* **59**:139–157 (1978).
16 *Norma IRAM 15931*. Instituto Argentino de Normalización (1994).
17 *Norma IRAM 15932*. Instituto Argentino de Normalización (1994).
18 *Norma IRAM 15941-2*. Instituto Argentino de Normalización (1997).

19 *AOAC Method 980.23*. Association of Official Analytical Chemists (1990).
20 *Norma IRAM 15937-2*. Instituto Argentino de Normalización (1995).
21 Tellería MC, Caracterización botánica y geográfica de las mieles de la provincia fitogeográfica pampeana (República Argentina) I: Distrito Oriental. *Darwiniana* **31**:345–350 (1992).
22 Andrada A, Valle A, Aramayo E and Lamberto S, Espectro polínico de las mieles de la región de Bahía Blanca, provincia de Buenos Aires, Argentina. *Polen* **9**:75–84 (1998).
23 Tellería MC, Analyse pollinique des miels du nord-ouest de la province de Buenos Aires (République Argentine). *Apidologie* **19**:275–290 (1988).
24 Tellería MC, Caracterización botánica y geográfica de las mieles de la provincia fitogeográfica pampeana (República Argentina) II: Tandilia. *Bol Soc Argent Bot* **32**:91–94 (1996).
25 Bogdanov S, Honey quality, methods of analysis and international regulatory standards: review of the work of the International Honey Commission. *Mitt Lenbensm Hyg* **90**:107–125 (1999).
26 *Código Alimentario Argentino Actualizado, Anexo Mercosur*. De la Canal & Asociados SRL, Buenos Aires (1995).
27 Mendes E, Brojo Proença E, Ferreira IMPLVO and Ferreira MA, Quality evaluation of Portuguese honey. *Carbohyd Polym* **37**:219–223 (1998).
28 Sporns P, Plhak L and Friedrich J, Alberta honey composition. *Food Res Int* **25**:93–100 (1992).
29 Golob T and Plestenjak A, Quality of Slovene honey. *Food Technol Biotechnol* **37**:195–201 (1999).
30 Brice BA, Turner Jr A and White Jr JW, Glass color standards for extracted honey. *Assoc Off Agric Chem* **39**:919–937 (1956).