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ORIGINAL ARTICLE

Physicochemical properties of some honeys produced from different plants in Morocco

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Abstract Seventy-three Moroccan honey samples were collected between 2005 and 2008. In this study, water content, pH, acidity (free, lactone and total acidity), electrical conductivity (EC), colour, diastase, hydroxymethylfurfural (HMF) and sugar content were all determined in different types of bee honey which include multifloral, honeydew and nine types of unifloral honeys (*Euphorbia resinifera*, *Euphorbia echinus*, *Citrus*, eucalyptus, carob, thyme, lavender, *Ziziphus* and rosemary). The moisture shows values of 14.3% and 20.2%, pH between 3.52 and 5.13, the total acidity ranges between 11.94 and 58.03 meq kg^{-1}, hydroxymethylfurfural (HMF) content shows values between 0.09 and 53.38 mg kg^{-1}; diastase values were between 4.3° and 24.6° Gothe; electrical conductivity between 119.9 and 1741 μs cm^{-1} and fructose, glucose and sucrose values range between 35.07–46.26%, 23.7–39.3% and 0.42–2.98%.

A statistical analysis was carried out to classify 10 types of honeys, and identified the most significant parameters, using analysis of variance, principal component analysis (PCA) and stepwise discriminant analysis (SDA). PCA showed that the cumulative variance was 74.97% and about 88.9% of samples was correctly classified.

The principal aim of this study was to contribute more to the knowledge of the Moroccan honeys by means of the analysis of chemical composition and of physical parameters. Seventy-three

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Moroccan unifloral, multifloral and honeydew honey samples, including types that have never been studied before, produced in different regions in Morocco (Tables 1 and 2), were analysed to define its main features.

As a consequence, we present data on water content, electrical conductivity, pH, free acidity, lactone acidity, total acidity, diastase, 5-(hydroxymethyl)-2-furaldehyde (HMF) amounts, fructose, glucose and sucrose.

1. Introduction

Morocco is a valid territory for honey production, due to its melliferous variety sources. Beekeeping is an old activity and 80% of the productivity is due to traditional beekeeping.

In 2006, honey production has reached 3500 ton of which 2500 ton is from the industrial sector and 1000 ton is from traditional methods, an increase of about 17% over 2005. The number of beekeepers is about 35,000 including 26,000 traditional and 9000 modern beekeepers. The number of hives is 385,000 of which 300,000 were traditional and 85,000 modern hives (Ministère de l'Agriculture et de la Pêche Maritime, Morocco, 2006).

Honey composition depends highly on the type of flowers utilised by the bee as well as the climatic conditions (Abu-Tarboush et al., 1993). The Moroccan honey productions regard many types of floral origin (Díez et al., 2004; Terrab et al., 2003a,b,c); many researchers have published studies about their parameters especially in Northwest of Morocco (Belouali et al., 2008; Naman et al., 2005, Noaman et al., 2004; Terrab et al., 2001, 2002, 2003a,b,c,d).

In Morocco, honey is widely used in traditional medicine, unfortunately, there are not enough investigations regarding its quality and characterisation, and *Euphorbia echinus*, *Ziziphus lotus* and lavender honeys were never studied.

Three races of bees that live in Morocco (Hepburn and Radloff, 1998) are *Apis mellifera intermissa* (Buttel-Reepen, 1906) present in most regions, *Apis mellifera major* (Ruttner, 1987) in the Rif mountains in the North, and it is considered as an ecotype not differing from *Apis mellifera intermissa* in behaviour and its taxonomic status, and *Apis mellifera sahariensis* (Baldensperger, 1932) in the South.

Table 1 Unifloral honey samples.

No. samples	Honey type	Production region	Production year
1	*Euphorbia echinus*	Souss Massa	2005
1	*Euphorbia echinus*	Souss Massa	2006
2	*Euphorbia echinus*	Souss Massa	2007
3	*Euphorbia resinifera*	Tadla Azilal	2006
9	*Euphorbia resinifera*	Tadla Azilal	2007
3	*Citrus*	Souss Massa	2007
3	*Citrus*	Tadla Azilal	2007
2	*Citrus*	Tadla Azilal	2008
2	*Citrus*	Tensift Al Haouz	2006
6	*Citrus*	Tensift Al Haouz	2007
1	*Citrus*	Tensift Al Haouz	2008
1	Eucalyptus	Chaouia	2005
1	Eucalyptus	Gharb	2007
1	Eucalyptus	Oriental	2007
1	Eucalyptus	Tadla Azilal	2007
3	Eucalyptus	Tensift Al Haouz	2007
2	Carob	Gharb	2007
1	Carob	Tadla Azilal	2006
2	Thyme	Gharb	2007
1	Thyme	Tadla Azilal	2007
1	Lavender	Gharb	2007
1	Lavender	Tafilalet	2007
1	*Ziziphus*	Gharb	2007
1	*Ziziphus*	Oriental	2007
1	*Ziziphus*	Souss Massa	2007
1	*Ziziphus*	Tensift Al Haouz	2007
1	Rosemary	Oriental	2007
1	Rosemary	Gharb	2007

2. Materials and methods

2.1. Honey samples

Seventy-three unifloral, multifloral and honeydew honey samples were collected from beekeepers in different regions of Morocco between 2005 and 2008, during different seasons of the year depending on floral sources (*Euphorbia*, C*itrus*, eucalyptus, carob, thyme, lavender, Z*iziphus* and rosemary). The informations about samples are presented in Tables 1 and 2.

2.2. Analytical procedures

Water content (moisture) was determined by an Abbe-type refractometer reading at 20 °C, according to the relationship between honey water content and refractive index (Bogdanov, 2002; Chataway, 1932).

Table 2 Multifloral and honeydew honey samples.

No. samples	Honey type	Production region	Production year
2	Multifloral	Chaouia	2006
1	Multifloral	Chaouia	2007
2	Multifloral	Gharb	2007
1	Multifloral	Oriental	2007
2	Multifloral	Tadla Azilal	2007
1	Multifloral	Tadla Azilal	2008
3	Multifloral	Tafilalet	2006
1	Multifloral	Tafilalet	2007
3	Multifloral	Tensift Al Haouz	2006
1	Multifloral	Zaer	2007
1	Honeydew	Tensift Al Haouz	2007
1	Honeydew	Oriental	2007

pH was measured by means of a potentiometric pH-metre (Hanna Instruments) in a solution containing 10 g of honey in 75 ml of CO_2 free distilled water. Free, lactone and total acidities were determined by a titrimetric method as follows: the addition of 0.05 M NaOH is stopped at pH 8.5 (free acidity), immediately a volume of 10 ml containing 0.05 M NaOH is added and, without delay is back titrated with 0.05 M HCl to pH 8.3 (lactone acidity). Total

Table 3 Water content, acidity and hydroxymethylfurfural.

Honey type	Water content (%)	pH	Free acidity (meq/kg)	Lactone acidity (meq/kg)	Total acidity (meq/kg)	L. acidity/ F. acidity	HMF (mg/kg)	Diastase (° Gothe)
Citrus								
Mean	17.47	3.91	16.52	7.20	23.73	2.38	7.16	7.37
Range	15–20.19	3.51–4.23	8.85–42.63	2.68–10.84	11.93–50	1.41–5.78	0.08–32.60	4.3–11.00
SD	0.35	0.04	1.88	0.51	2.13	0.25	1.97	0.44
Eucalyptus								
Mean	17.01	4.24	19.34	9.70	29.03	2.02	20.07	13.17
Range	14.96–19.63	3.9–4.57	15.79–23.92	6.75–11.54	22.55–34.79	1.65–2.34	3.25–43.87	6.5–21.20
SD	0.56	0.08	1.04	0.61	1.55	0.09	6.53	2.34
Carob								
Mean	18.59	4.29	19.76	7.49	27.25	2.79	17.80	10.53
Range	18–19.76	4.21–4.43	17.92–22.39	5.03–9.39	24–31.78	2.22–3.77	15.12–19.70	9.1–11.90
SD	0.59	0.07	1.35	1.29	2.33	0.49	1.38	0.81
Thyme								
Mean	16.69	4.14	28.15	11.46	39.61	2.45	30.43	18.20
Range	16.43–17.18	3.86–4.33	24.15–31.43	10.5–12.63	34.65–44.05	2.30–2.57	10.48–53.38	10.70–26.60
SD	0.24	0.14	2.13	0.62	2.72	0.08	12.47	4.61
E. resinifera								
Mean	17.06	4.23	18.24	7.83	26.07	2.39	12.08	12.67
Range	15–19	4.09–4.41	15.70–21.71	5.43–9.30	21.99–30.35	1.70–3.54	0.37–23.44	7.90–17.30
SD	0.34	0.04	0.59	0.41	0.75	0.16	2.18	0.76
E. echinus								
Mean	17.88	4.22	24.16	8.70	32.86	2.92	20.32	17.25
Range	16.5–19	4.08–4.43	17.51–29.87	6.18–12.53	23.69–42.40	2.20–4.25	8.24–37.43	10.5–29.60
SD	0.66	0.08	3.08	1.44	4.02	0.46	7.08	4.39
L. stoechas								
Mean	16.87	3.98	30.74	12.78	43.51	2.41	17.85	15.65
Range	16.27–17.46	3.89–4.06	27.72–33.76	12.75–12.81	40.46–46.57	2.17–2.64	13.58–22.12	15.60–15.70
SD	0.60	0.08	3.02	0.03	3.05	0.23	4.27	0.05
Ziziphus								
Mean	16.65	4.45	20.89	7.19	26.09	2.93	8.71	15.63
Range	16.27–17	4.27–4.63	13.10–25.45	5.87–9.50	18.98–32.97	2.23–3.60	2.65–21.86	14.30–16.30
SD	0.16	0.08	2.75	0.86	2.88	0.33	4.42	0.47
Honeydew								
Mean	14.64	4.93	21.40	4.68	26.09	4.61	1.87	19.10
Range	14.29–15	4.72–5.13	15.97–26.84	4.53–4.84	20.81–31.37	3.30–5.92	1.52–2.21	12.30–25.90
SD	0.36	0.21	5.43	0.15	5.28	1.31	0.34	6.80
Rosemary								
Mean	16.37	3.98	10.69	6.26	16.95	1.71	23.88	6.05
Range	16.27–16.47	3.95–4.00	10.10–11.27	5.73–6.79	15.83–18.06	1.66–1.76	12.05–35.71	6.00–6.10
SD	0.10	0.02	0.59	0.53	1.12	0.05	11.83	0.05
Multifloral								
Mean	17.08	4.05	20.68	8.04	28.72	2.55	12.91	11.88
Range	15–19.60	3.75–4.71	10.41–44.09	5.40–14.17	16.12–58.03	1.82–3.53	0.63–52.75	5.90–21.80
SD	0.27	0.07	2.31	0.74	3.01	0.12	3.63	1.00
Total								
Mean	17.14	4.13	19.69	8.07	27.64	2.51	13.40	11.91
Range	14.29–20.20	3.52–5.13	8.86–44.09	2.68–14.17	11.94–58.03	1.42–5.92	0.09–53.38	4.30–29.60
SD	0.15	0.03	0.85	0.30	1.07	0.10	1.52	0.63

acidity results are obtained by adding free and lactone acidities (Bogdanov et al., 1997).

The detection method of hydroxymethylfurfural (HMF) was based on the original work of Jeuring and Kuppers (1980) suggested by the European Honey Commission (Bogdanov et al., 1997). HMF was determined in a clear, filtered, aqueous honey solution using reverse phase HPLC (high pressure liquid chromatography) equipped with UV detection. Separation was performed on an octadecylsilane C18 column 150 × 4.6 mm, 5 μm particle size. The signal was compared with those from standards of known concentration.

Table 4 Electrical conductivity, colour and sugar contents.

Honey type	Electrical conductivity (μs cm^{-1})	Colour (mm Pfund)	Fructose (%)	Glucose (%)	Sucrose (%)
Citrus					
Mean	313.35	26.00	39.71	29.25	1.06
Range	192–480	11–62.00	37.43–44.84	23.70–37.71	0.23–2.52
SD	18.52	3.65	0.58	0.94	0.17
Eucalyptus					
Mean	768.78	91.71	39.37	32.02	0.47
Range	381–1141.27	41–147.00	37.02–41.93	29.33–37.30	0.23–0.79
SD	96.70	13.34	0.60	1.04	0.09
Carob					
Mean	900.22	91.33	39.77	32.53	0.82
Range	785–1104.49	83–99	38.82–40.49	30.72–33.50	0.38–1.59
SD	102.41	4.63	0.49	0.91	0.39
Thyme					
Mean	535	116.33	39.44	30.56	1.86
Range	350–755	111–119	37.22–40.96	26.13–33.81	0.57–2.60
SD	118.22	2.67	1.14	2.29	0.65
E. resinifera					
Mean	410.62	71.80	40.85	29.98	0.97
Range	240–696.96	30–146	35.88–45.18	25.45–34.46	0.25–2.35
SD	46.39	10.10	0.80	0.73	0.25
E. echinus					
Mean	582.49	102.75	41.70	28.33	1.05
Range	414.3–735.68	83–119	40.47–43.73	24.35–31.05	0.74–1.45
SD	66.51	7.75	0.78	1.41	0.15
L. stoechas					
Mean	433.00	110.50	41.19	27.79	0.61
Range	319–547	71–150	40.34–42.04	27.07–28.50	0.25–0.96
SD	114.00	39.50	0.85	0.71	0.36
Ziziphus					
Mean	673.42	84.75	39.66	29.43	0.61
Range	422–1096.74	51–110	35.07–43.04	26.64–32.06	0.43–0.71
SD	150.04	12.95	1.73	1.40	0.07
Honeydew					
Mean	1119.28	124.50	42.42	32.27	1.59
Range	497.55–1741	99–150	41.54–43.29	31.31–33.23	0.74–2.43
SD	621.72	25.50	0.87	0.96	0.85
Rosemary					
Mean	129.95	39.50	42.17	32.66	1.63
Range	119.90–140	28–51	41.53–42.82	32.60–32.71	0.28–2.98
SD	10.05	11.50	0.65	0.05	1.35
Multifloral					
Mean	407.44	63.33	40.57	33.08	1.26
Range	150–1142.24	18–96	36.60–46.29	25.14–39.31	0.24–2.81
SD	63.40	6.89	0.69	1.05	0.22
Total					
Mean	487.25	67.74	40.32	30.77	1.05
Range	119.90–1741	11–150	35.07–46.29	23.70–39.31	0.24–2.98
SD	35.07	4.58	0.28	0.43	0.09

Electrical conductivity was measured at 20 °C in a conductimeter; the sample solution was prepared using ultra pure water (Vorwohl, 1964).

Diastase was measured using Phadebas method based on the procedure of Siegenthaler (1975), modified by Bogdanov (1984) and harmonised by the European Honey Commission (Bogdanov et al., 1997). Adsorption was determined using a spectrophotometer UV/VIS at $\lambda = 620$ nm.

Sugar content was determined by HPLC with RI (refractive index) detector and analytical stainless-steel column in polar aminopropylsilane (–NH_2) (5 μm) 250 × 4.6 mm. In a 100 ml volumetric flask, containing 25 ml of methanol, 5 g of honey dissolved in water were transferred and filled up with water. The solution was filtered through a 0.45 μm syringe filter (Bogdanov et al., 1997; Bogdanov and Baumann, 1988).

Colour was measured according to Pfund colour scale, using the Lovibond comparator; the reading is expressed in millimetres.

2.3. Statistical analysis

Statistical Package for Social Science (SPSS) was used to establish the difference between the 10 honey types by mean of their physicochemical parameters. The results are expressed as mean values, range of values and standard deviation (SD) using analysis of variance (ANOVA). In order to check if the correlation matrix can be presumed to be the identity; Bartlett test of sphericity and the KMO test (Kaiser–Meyer–Olkin measure of sampling adequacy) were performed. We proceeded to carry out a study of the bivariate correlations between all the variables, detecting which of them were significant. With the aim of evaluating which of the main factors identified will explain most of the variability, the data matrix was submitted to principal component analysis (PCA), using the covariance matrix. A stepwise discriminant analysis (DA) technique was performed in an attempt to classify the honey samples.

3. Results and discussion

3.1. Physicochemical parameters

The means, ranges of values and standard deviations of water content, acidity, hydroxymethylfurfural, electrical conductivity, colour and sugar content are listed in Tables 3 and 4.

Moisture is a parameter related to the maturity degree of honey and temperature. In the present study moisture values are between 14.3% and 20.2%. One sample with 20.2% exceeded the limit (20%) allowed by European Community regulations (The Council of the European Union, 2002). Moisture values were within the values found in Algerian honeys (between 14.64% and 19.04%) (Ouchemoukh et al., 2006) and less than those found in Northwest Moroccan honeys (between 14% and 24.1%) (Terrab et al., 2002), which confirm that the moisture content is also affected by climatic conditions (Nanda et al., 2003).

Acidity of honey due to the presence of organic acids, pH values were between 3.52 and 5.13, according with the values found in Algerian honeys (Ouchemoukh et al., 2006). Values for free acidity ranged from 8.86 to 44.09 meq kg^{-1}; the lactone acidity ranged between 2.68 and 14.17 meq kg^{-1}, while the total acidity ranged between 11.94 and 58.03 meq kg^{-1}. Values for free acidity were below the allowed limits (50 meq kg^{-1}) (The Council of the European Union, 2002), showing the absence of undesirable fermentation.

Hydroxymethylfurfural (HMF) content, an indicator of honey freshness (schade et al., 1958), shows values between 0.09 and 53.38 mg kg^{-1}; four samples with values between 90.76 and 783 mg kg^{-1} exceeded the limits established by European Community regulations (The Council of the European Union, 2002) due to excessive heating.

Diastase shows values between 4.3° and 24.6° Gothe, four samples exceeded the limits of European Community Regulation (The Council of the European Union, 2002) with values less than 8° Gothe and HMF content more than 15 mg kg^{-1}.

Electrical conductivity, closely related to the concentration of mineral and organic acids, shows great variability according to the floral origin. Values were between 119.9 and 1741 μs cm^{-1} and within the values found in Algerian (mean ranged between 210 and 1610 μs cm^{-1}) (Ouchemoukh et al., 2006 and Northwest Moroccan honeys (between 240 and 1734 μs cm^{-1}) (Terrab et al., 2002) .

Fructose, glucose and sucrose values range between 35.07–46.26%, 23.7–39.3% and 0.42–2.98%, being within the values found in Northwest Moroccan (ranges: 29–41%, 24–35% and 0–5%) (Terrab et al., 2001), French (29.56–42.9%, 22.25–42.4% and 0–5.3%) (Devillers et al., 2004) and Spanish (31.9–40.6%, 22.7–37.8% and 0.02–12%) honeys (Mateo and Bosch-Reig, 1998). The maximum value of sucrose, present in all honey samples, is below the maximum found in the last studies (Terrab et al., 2001; Devillers et al., 2004; Mateo and Bosch-Reig, 1998) and within the limit (< 5%) allowed by the European Community requirements (The Council of the European Union, 2002).

3.1.1. Euphorbia (Euphorbia resinifera, Euphorbia echinus) honeys

Euphorbia resinifera and *Euphorbia echinus* are both Morocco endemic plants, occurring on the slopes of the Atlas Mountains. *E. resinifera* is more widespread in the surroundings of Tadla Azilal, while *E. echinus* is present more in the Agadir and Tiznit surroundings. This type of honey lacking studies of its physicochemical properties; *E. resinifera* honey has strong antimicrobial activity on bacterial strains (Noaman et al., 2004); it has a pungent flavour, very much appreciated by the Moroccan customers and highly used in traditional medicine.

Appearance: liquid or crystallised, the colour can be from golden yellow to dark amber. Taste: sweet, pinch in the throat with a typical light bit back flavour.

The mean value of water content was 17.3%, free acidity 19.93 meq kg^{-1} and HMF 14.43 mg kg^{-1}. The value of diastase 13.98° Gothe was relatively higher than in the other samples and electrical conductivity showed a mean value of 460 μs cm^{-1}; previous values are within the results found by Naman et al. (2005). The *E. echinus* honey shows values of colour, free acidity, HMF, diastase and electrical conductivity higher than those of *E. resinifera* honey.

3.1.2. Thyme (Thymus spp.) honeys

Appearance: crystallises spontaneously after a few months, the crystals are often irregular, aroma: intense, distinctive, floral and spicy at the same time, the dried flowers, cloves and aromatic herbs. The colour is always more or less amber. Taste: Normally sweet with a typically spiced flavour.

The antimicrobial activities of this type of honey were similar to those of Euphorbia honeys (Noaman et al., 2004). In the Mediterranean area, the thyme honeys are mainly produced in Greece, Italy, Morocco and Spain (Ricciardelli D'Albore, 1998).

In this study, thyme honey shows higher value of electrical conductivity (535 μs cm^{-1}) than the values found in Italian (Persano Oddo et al., 2000), Spanish (Terrab et al., 2004) and Moroccan (Naman et al., 2005) honeys; (390, 243 and 395 μs cm^{-1}, respectively).

Water content 16.69% and pH 4.14 were within those found in Italian (Persano Oddo et al., 2000), Spanish (Terrab et al., 2004) and Polish (Juszczak et al., 2009) honeys, Naman et al. (2005) in Moroccan honeys found relatively high values of water (between 19.89% and 21.8%) and pH (between 4.42 and 4.5), however diastase 18.2° Gothe was very low compared with values found in the same studies (Persano Oddo et al., 2000; Terrab et al., 2004; Naman et al., 2005).

3.1.3. Rosemary (*Rosmarinus officinalis*) honeys

Appearance: crystallized a few months after harvest, often fine-grained, colour from pale yellow to almost colourless when liquid, white to ivory when crystallized. Smell: generally weak, not very characteristic, finely aromatic, herb, slightly floral. Taste: normally sweet. Aroma: light, floral, bitter almonds, not very persistent.

Water content, pH, electrical conductivity (16.37%, 3.98 and 130 μs cm^{-1}, respectively) and the sugar content values were within those found in Italian (Persano Oddo et al. 2000) and Spanish (Mateo and Bosch-Reig (1998) honeys; however free acidity was 10.69 meq kg^{-1} and diastase 7.3° Gothe showed sensitively lower values than the last studies, on the other hand HMF of 23.88 mg kg^{-1} was higher than the values found in the same studies. Electrical conductivity, pH, moisture, acidity, sucrose and fructose/glucose values were within the values found in Spanish rosemary honey (Pérez-Arquillué et al., 1994).

3.1.4. Orange (*Citrus* spp.) honeys

Orange honey is the most popular honey produced in Morocco. Appearance: often crystallized quickly after production. The colour is pearly light yellow depending on honey crystallization. Taste: sweet gently acidulous, with the flavour of fruits and flowers.

This type of honey showed a low HMF content (7.16 mg kg^{-1}) and light colour (26 mmPfund). Water content, pH, and free acidity (17.47%, 3.91 and 16.52 meq kg^{-1}, respectively) were within the values found in Italian (Persano Oddo et al., 2000), Northwest Moroccan (Terrab et al., 2003b), Andalusian (Serrano et al., 2004) and Algerian (Chefrour et al., 2007) honeys.

Sugars and diastase values are low than those found in Italian honeys (Persano Oddo et al. 2000), the electrical conductivity value, 313 μs cm^{-1}, was relatively higher than the value found in the previous studies.

3.1.5. Eucalyptus (*Eucalyptus* spp.) honeys

Appearance: usually crystallized. The colour is amber with yellow grey reflections. Taste: normally sweet, with a very peculiar flavour. Light back flavour typically salted, remember liquorice.

Water content, fructose and glucose (17.01%, 39.37%, 32.02%) were within the values found in Italian (Persano Oddo et al., 2000), Northwest Moroccan (Terrab et al., 2003a) and Andalusian (Serrano et al., 2004) honeys, pH (4.24) was within the values found in Italian and Andalusian honeys and relatively higher than the value found in Northwest Moroccan honeys, electrical conductivity value (768.78 μs cm^{-1}) was in accord with the last study (Terrab et al., 2003a) and higher than the other ones (Persano Oddo et al., 2000; Serrano et al., 2004).

3.1.6. Ziziphus (*Ziziphus lotus*) honeys

This type of honey is poorly studied; it has been characterised by a high value of electrical conductivity (673 μs cm^{-1}). Water content (16.65%) and diastase (15.63° Gothe), were similar to those found in Pakistani ziziphus honeys (Asif et al., 2002); however, pH (4.45), HMF (8.71 mg kg^{-1}) and sucrose (0.61%) are very lower than those found in the last study.

3.1.7. Carob (*Ceratonia siliqua*) honeys

The values of water content, pH, free acidity and HMF (18.59%, 4.29, 19.76 meq kg^{-1} and 17.8 mg kg^{-1}, respectively) agree with the results found by Terrab et al. (2003c), the electrical conductivity value (900 μs cm^{-1}) is higher than the one found in the last study (679 μs cm^{-1}).

3.1.8. Lavender (*Lavandula* spp.) honeys

Appearance: normally crystallized. The colour is from very light to amber. Taste: sweet and sour at the same time with a typically fruited back flavour.

This honey type is characterised by its high values of colour, electrical conductivity and free acidity (110.5 mmPfund, 433 μs cm^{-1} and 30.74 meq kg^{-1}), values higher than those found in French (33.6 mmPfund, 221.2 μs cm^{-1} and 14.86 meq kg^{-1}) (Devillers et al., 2004) and Spanish (166 μs cm^{-1} and 14 meq kg^{-1}) (Pérez-Arquillué et al., 1995) honeys. On the other hand water content, pH, fructose and glucose are within the values found in the previous studies.

3.1.9. Honeydew honeys

Appearance: often remains liquid for a long, dark amber colour if iquido pitch black, brown when crystallized. Flavour: medium intensity, vegetable/fruit, stewed fruit. Taste: Not too sweet, sometimes a little jump, medicine syrup (Not too sweet, caramelized).

This type of honey showed the following mean values: water content 14.64%, pH 4.92, free acidity 21.40 meq kg^{-1}, HMF 1.87 mg kg^{-1}, electrical conductivity 1119 μs cm^{-1}, diastase 19.1° Gothe and colour 124.5 mmPfund.

Values of pH, diastase and sugars are higher than those found in Northwest Moroccan honeydew honey (Terrab et al., 2002; Díez et al., 2004). Authors in the same studies found values of water content, free acidity, HMF and electrical conductivity higher than those found in the present study; however water content and pH values are within the values found in Turkish honeys (Kayacier and Karaman, 2008).

3.2. Statistical analysis

From the KMO ($p = 0.588$) and Bartlett ($p < 0.001$) tests it can be concluded that there is a significant intercorrelation between the variables represented by the differently analysed

Table 5 Total variance explained.

Component	Initial eigenvalues			Extraction sums of squared loadings		
	Total	% Of variance	Cumulative (%)	Total	% Of variance	Cumulative (%)
1	3.53	27.17	27.17	3.53	27.17	27.17
2	2.41	18.53	45.70	2.41	18.53	45.70
3	1.46	11.22	56.92	1.46	11.22	56.92
4	1.28	9.85	66.78	1.28	9.85	66.78
5	1.06	8.19	74.97	1.06	8.19	74.97
6	0.88	6.74	81.70			
7	0.79	6.06	87.77			
8	0.57	4.39	92.15			
9	0.49	3.76	95.91			
10	0.35	2.72	98.63			
11	0.16	1.22	99.85			
12	0.01	0.10	99.95			
13	0.01	0.05	100.00			

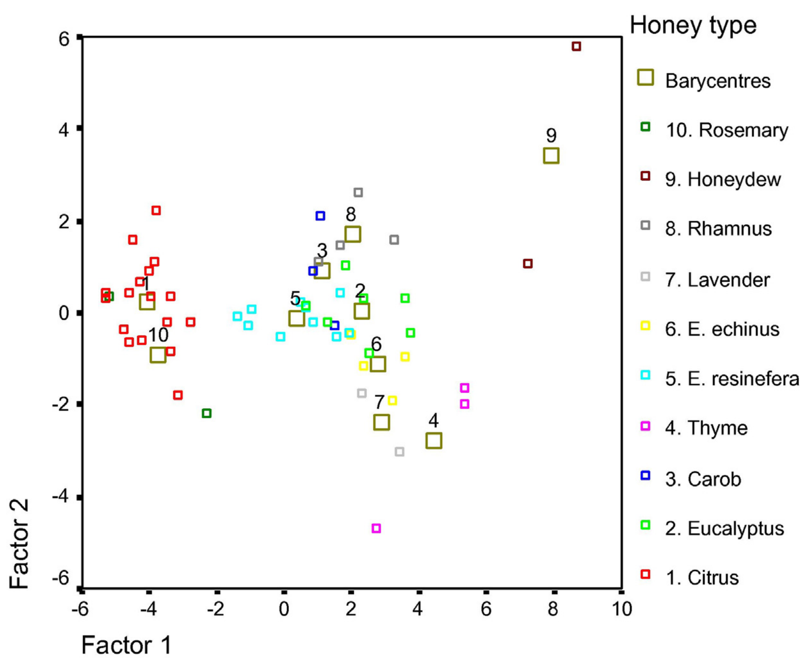

Figure 1 Plot of the first factor versus second factor, for classification of 10 unifloral honeys.

parameters, and the data matrix can proceed for factorial analysis. In order to classify the 10 types of honeys by their physicochemical properties, a standardised PCA was used. From Table 5 it can be concluded that 74.97% of the variation existing in the data can be explained by five factors.

Fig. 1 shows the groups formed by different unifloral honeys. Honeydew honeys are different from the other honey types; and these results agree with Terrab et al. (2002).

Table 6 lists the percentage of the variance explained for each factor and variables which load highly to the first factor based on acidity, colour, HMF and diastase. The variables which correlate highly on the second factor are pH, electrical conductivity and lactone acidity/free acidity, the addition of the first and second one agree with the result of Sanz et al. (1995) who classified honeys based on their acidity, pH, electrical conductivity, ash, HMF and diastase; however, Terrab et al. (2002) established water content, free acidity, lactone

Table 6 Component matrix.

	Component				
	1	2	3	4	5
Total acidity	0.927	−0.245	0.197	0.094	−0.052
Free acidity	0.920	−0.109	0.292	0.109	−0.131
Lactone acidity	0.724	−0.550	−0.171	0.033	0.209
Colour	0.666	0.378	−0.347	−0.115	0.144
HMF	0.532	−0.263	−0.171	−0.221	0.295
Diastase	0.525	0.324	−0.262	0.448	−0.039
pH	0.067	0.870	−0.231	−0.174	0.001
Electrical conductivity	0.409	0.595	−0.082	−0.539	0.008
Lactone acidity/free acidity	0.342	0.563	0.558	0.050	−0.406
Sucrose	−0.003	0.128	0.751	−0.042	0.320
Fructose	−0.009	0.270	−0.032	0.734	−0.005
Glucose	−0.062	0.198	0.354	−0.010	0.656
Water content	0.087	−0.401	0.161	−0.363	−0.441

acidity, and proline as classification factors on the other hand electrical conductivity, free acidity, proline and pH found by Krauze and Zalewski (1991) as classification factors. From the study of Pena-Crecente and Herrero Latorre (1993) we can conclude that water content and acidity were classification parameters. The third and fourth factors are formed by sucrose and fructose, respectively. The variables that load higher to the fifth factor are related to glucose and water content.

In order to test the homogeneity of covariance matrices Box's M Test was used, it was significant, it is concluded that the covariance matrices of the group differ.

The variables selected by stepwise discriminant analysis were pH, lactone acidity, total acidity, diastase, electrical conductivity and colour. This fact is corroborated by the Wilks test being significant ($p < 0.001$). The 10 samples were 87% correctly classified.

4. Conclusion

The types of honey analysed constitute the main Morocco melliferous productions. *E. echinus*, *Z. lotus* and lavender Moroccan honeys have been investigated for the first time for their physicochemical parameters.

In general, the results of the present study were within those found in previous studies about physicochemical properties of Moroccan honeys (Terrab et al., 2001, 2002, 2003a,b,c; Díez et al., 2004; Naman et al., 2005).

The cumulative variance is approximately 74.96%, showing that the 10 honey types are not well distinguished by their physicochemical parameters. Melissopalynological analyses, being the best method to distinguish honey's botanical and geographical origins and to obtain their characterisation (Ferrero and Ferrazzi, 2008), will be applied to the examined samples, but physicochemical parameters are very important to determine the honey quality.

As regards to the basic parameters that warrant the honey quality, water content and HMF previously complying with values proposed by Bogdanov et al. (1997) and The Council of the European Union (2002); a deeper professional education would be necessary to promote Moroccan beekeepers vocational training.

The knowledge of physicochemical features of Moroccan honeys is very important in order to set up certification marks and improve the local beekeeping, also for a possible export.

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