Journal of Food and Drug Analysis, Vol. 13, No. 4, 2005, Pages 331-337 藥物食品分析 第十三卷 第四期

Sensory Evaluation and Chemical Analysis of *Apis mellifera* Honey from the Arab Gulf Region

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(Received: January 12, 2005; Accepted: May 12, 2005)

ABSTRACT

Twenty-one honey samples, both collected directly from the hive and purchased from retail sources, were used in this study. Significant differences existed among the samples in terms of color, smell, thickness, mouth feel (texture), taste, sweetness, and aftertaste. Water content ranged from 11.1% to 19.8% and fructose and glucose represented the major sugar forms in all 21 samples. Fructose percentages ranged from 33.1% to 39.0%. Glucose percentages ranged from 25.6% to 37.3%. Trace amounts of sucrose were detected in most honey samples, with percentages ranging from 0.10% to 0.37%. Total sugar in the samples ranged from 64.9% to 80.4%. The glucose percentages in samples indicated all samples were fast granulating, while glucose/water ratios indicated that several samples were had non-granulating tendencies. All samples had fructose to glucose ratios greater than 1.0. Twelve of the 21 samples may have misleading glucose to water ratios, associated with low indices ranging from 1.01 to 1.14, and their data did not fit well with previously reported studies. In this study, a sample with a glucose/water ratio of ≥ 1.0 indicated a tendency to granulate rapidly, as compared to other granulating indices. The fructose to glucose ratio may not be the best index for granulation tendency. Based on the ratio of (glucose-water) to fructose, several honey brands had a lower granulation tendency; a finding in agreement with glucose to water ratio results. Differences between fructose and glucose contents ranged from 0.4% to 10.0%. Good correlations were found between sensory evaluations and chemical analyses of honey samples. The results of this study may help improve researchers' understanding of of honey properties and their impact on consumer preference.

Key words: *Apis mellifera*, Arab Gulf region, honey, sensory evaluation

INTRODUCTION

Honey is a sweet, viscous liquid that bees produce from nectar collected from plant nectaries and store as food. Honey is an easily digestible foodstuff that contains a range of nutritionally important compounds[11]. The major components of honey include various saccharides, water, amino acids, mineral matter, proteins, vitamins, and unstable compounds such as enzymes[5,7,18,27,29,34]. Significant differences exist between honey brands in terms of flavor and aroma profiles.

Honey moisture content, a critical variable influencing product quality, granulation and texture, is significantly affected by conditions under which honey is stored following its extraction from the hive. Simple sugars, glucose and fructose predominate, give honey its sweetness, energy value, and physical characteristics[27,29,34].

Sensory evaluation is an important tool employed in determining / defining honey quality. Many studies have already been done and published on physicochemical and sensory analyses[1,11,14,17,31], on qualitative differences between honeys of different botanical origins, regions and commercial sources[1], and the effect of principal chemical constituents on honey quality[3,15,18,27].

Honey, a highly concentrated solution of simple sugars, contains more dissolved solids than can remain dissolved under normal conditions[25]. The tendency of honey to granulate is directly related to several parameters (crystallization indices). These include glucose content and the ratios of glucose to water ratio, (glucose-water) to fructose, and fructose to glucose[5,6,21,25,35].

The two objectives of this study were (1) to conduct sensory evaluation to grade locally produced and imported *A. mellifera* honey samples and determine the overall acceptability of each sample and (2) to identify the chemical characteristics of honey samples obtained in the Arab Gulf region.

MATERIALS AND METHODS

I. *Honey Samples*

We used 13 *A. mellifera* honey samples for sensory evaluation and physicochemical analysis. Samples were either purchased in the UAE market (i.e., over-the-counter (OTC) products) or collected directly from the hives (HC). All samples varied in terms of origin and were coded accordingly (Table 1).

II. *Honeybee Species*

Data[19] on honeybee species in the Arab Gulf region is summarized in Table 2.

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Table 1. *Apis mellifera* local and imported honey samples used for sensory evaluation and physicochemical analyses

Product	Code	Honey trade name	Host / floral variety (plant Genus)	Color	Origin
OTC*	AL	Alalali	Orange	Dark brown	USA
	BE	Bee Easy	Various flowers	Light brown	USA
	DI	Diamond	Various flowers	Light brown	Australia
	LA	Langnese Black Forest	Forest trees	Amber	Germany
	NF	Nile Flower	Various flowers	Amber	New Zealand
	SA	Shifa Acacia	Acacia spp.	Light brown	Saudi Arabia
	SB	Sue Bee	Clover	Pale yellow	USA
	SL	Shifa Lime	Lime	Yellow	Saudi Arabia
	SO	Shifa Orange	Orange	Orange	Saudi Arabia
	UN	Unifood	Misc.	Light brown - golden	Australia
	WE	Weabenecht	Misc	Light brown	Germany
HC**	M1	Mixture 1	*Acacia, Zizaphus, Proposis, Salvadora, and Eucalyptus* spp.	Dark brown	UAE (Al-Oha)
	M2	Mixture 2	*Acacia, Zizaphus, Proposis, and Salvadora* spp.	Light brown	UAE (Al-Ain)
	M3	Mixture 3	*Acacia, Zizaphus, Proposis* spp., etc.	Black	Yemen (Soqatrah)
	M4	Mixture 4	Various trees and flowers	Dark brown	Yemen
	S1	Samar 1	Acacia spp.	Dark brown to black	UAE (Al-Oha)
	S2	Samar 2	Acacia spp.	Brown	UAE (Ain Khat)
	S3	Samar 3	Acacia spp.	Dark amber	Oman (Mahdah)
	Z1	Sidir 1	Zizaphus spp.	Light brown	UAE (Al-Oha)
	Z2	Sidir 2	Zizaphus spp.	Yellow	UAE (Al-Ain)
	Z3	Sidir 3	Zizaphus spp.	Yellow	Oman (Sahar)

*Over-the-counter product.
**Hive collected product.

Table 2. Honeybees in the Arab Gulf countries

	UAE	Oman	Saudi Arabia	Yemen
Bee species*	Amy, Amc	Amy, Amc, Af, Ac	Amy, Amsy, Amc	Amy, Amc
Date of introduction of modern beekeeping	1977	1976	1960	1976
Average annual honey yield (kg) per hive (date)	4.0 (1995)	5.9 (1995)	5.0 (1995)	6.0 (1996)
Total honey production (tons) (date)	78 (1995)	27 (1997)	270 (1995)	1706 (1996)
Honey g/person/year	54	11	23	108

*Ac: *Apis cerana indica,* Af : *A. florae,* Amc: *A. mellifera conica,* Amy: *A. mellifera yemenitica,* Amsy: *A. mellifera syriaca.*

III. *Sensory Evaluation*

A panel of 20 female students attending university in the UAE who regularly participate in sensory evaluation assignments evaluated all honey samples for color, smell, thickness, mouth feel (texture), taste, sweetness, and aftertaste. Honey samples used in the evaluation were presented to the panelists in generic containers and panelists were asked to rate evaluation variables accordingly (see Table 1): 1 = extreme dislike, 2 = strong dislike, 3 = moderate dislike, 4 = slight dislike, 5 = neutral, 6 = slight like, 7 = moderate like, 8 = strong like, 9 = extreme like. Differences in the physical properties of honey samples were analyzed using the Statistical Analysis System (SAS) program.

IV. *Chemical Analyses*

Analyses of the physico-chemical properties of honey samples were performed in accordance with EU-authorized testing methodologies[8]. Individual honey sample components were determined as follows:

(I) *Water Content*

A quantity of each of the 13 honey samples was placed in an oven at 70°C for one day. Differences in sample weights before and after drying were used to calculate sample water ratios.

(II) *Sugar Composition*

Ten grams of each of the 21 honey samples was measured, placed in a small beaker, and transferred into a mixer with 150 mL of water. The solution was centrifuged, filtered, and then injected through a 0.45 μm membrane filter. The percentages of the two monosaccharides (glucose and fructose) and one oligosaccharide (sucrose) in each honey sample were measured using high performance liquid chromatography (HPLC). Fructose, glucose, and sucrose were separated and quantified in 15 min under a flow rate of 1.5 mL/min and a temperature of approximately 35°C. Glucose levels and the ratios of glucose to water, glucose-water to fructose, and fructose to glucose were used to determine the tendency of individual honey samples to granulate.

(III) *Total Protein*

We used the Kjeldahl method to measure total protein content in each honey sample. The procedure for estimating the total protein percentage in honey samples followed both digestive and distillation phases.

(IV) *pH*

We measured honey sample acidity to determine the influence of pH on honey flavor / palatability as well as on processing requirements. Fifty milliliter of distilled water was added to 10 g of homogenized honey. A ROSS combination spear-tip pH-meter (model 250 A, Orion Research, USA) was used to measure pH values.

(V) *Mineral Elements*

Honey samples were analyzed for mineral content using an Inductively Coupled Argon Plasma Optical Emission Spectrometer (ICP-OES). Samples were digested using HNO_3 + $HClO_4$, then diluted to meet instrument conditions (Varian, Model Vista-MPX CCD, USA). The following minerals were analyzed: sodium, potassium, magnesium, calcium, phosphorus, iron, copper, manganese, zinc, chromium, and cobalt. The large linear range of the ICP, around 4~6 orders of magnitude for most elements, meant that relatively few dilutions were required to accommodate samples with wide concentration ranges.

V. *Statistical Analyses*

Statistical analyses were performed using the General Linear Model in the SAS computer package[31]. Treatment means, as reported in all Tables, were compared by the Least Significance Test (LSD) at $p < 0.05$.

RESULTS AND DISCUSSION

I. *Sensory Evaluation*

Our study found significant differences among the 13 honey samples in terms of color, smell, thickness, mouth feel (texture), taste, sweetness, and aftertaste (Table 3). The preference of panelists for Z1 honey over the remaining 12 samples, in all evaluated categories, represented a surprising finding. Z1 earned the highest category scores for color, aroma, thickness, texture, taste, and sweetness, while Z1 and S1 tied for the highest category score for aftertaste. Z1 was the honey most preferred by panelists, followed by SB and M1. In general, hive-collected honeys from the UAE received the highest scores from panelists. This indicates an intrinsic panelist bias toward honeys familiar to Emiratis and suggesting the possibility of different survey results if a panel with a different nationality profile was used.

II. *Physicochemical Characteristics*

(I) *Water Content*

Table 4 shows significant differences among the 13 honey samples in terms of water content, ranging from 11.1% in Z1 to 19.8% in DI. The results are in general agreement with the range reported in the literature (13~23%; average: 17%)[15,33,35]. Water content was reported to be about 23% in honey samples collected from Kerala, India[26], 18% in samples from Iraq[2], 14~17% in those from Connecticut, USA[18], 17~20 % in those from Spain[31], and 16.1% in samples from Austria[22]. Honey with a relatively high moisture content (more than 18%) may undergo yeast fermentation, leading to rapid increases in yeast and bacteria growth[6,28,30].

Table 3. Sensory evaluation of selected *A. mellifera* local and imported honey samples

Product	Code	Honey brand	Color	Aroma	Thickness	Texture	Taste	After taste	Sweetness	Overall acceptance
OTC*	AL	Alalali	5.1 cd**	5.5 ab	6.0 bc	6.5 abc	5.7 bcd	5.5 bcd	6.5 ab	6.4 abc
	BE	Bee Easy	6.4 abc	6.1 ab	7.0 ab	7.0 ab	6.5 abc	5.9 abc	6.7 ab	6.3 bc
	DI	Diamond	5.6 bc	4.7 b	6.1 abc	6.4 abc	5.5 bcd	5.2 bcd	6.2 ab	6.4 abc
	LA	Langnese Black Forest	6.3 abc	4.6 b	5.2 c	5.5 bcd	4.7 cd	4.6 cd	4.9 b	4.8 cd
	SA	Shifa Acacia	5.6 bc	5.5 ab	5.4 bc	6.3 abcd	5.3 bcd	5.1 bcd	5.7 b	5.4 bcd
	SB	Sue Bee	6.8 ab	5.8 ab	5.9 bc	6.9 abc	6.6 abc	5.6 bc	6.5 ab	6.7 ab
	SL	Shifa Lime	6.8 ab	6.0 ab	5.1 c	5.9 bcd	4.7 cd	5.4 bcd	5.7 b	5.3 bcd
	SO	Shifa Orange	6.9 ab	5.6 ab	5.2 c	5.4 cd	3.9 d	3.7 d	5.2 b	4.4 d
	UN	Unifood	3.9 d	4.7 b	5.8 bc	4.9 d	5.8 abcd	5.6 bc	6.4 ab	5.8 bcd
	WE	Weabenecht	6.4 abc	5.0 b	4.9 c	5.8 bcd	5.5 bcd	4.5 cd	5.2 b	5.0 bcd
HC***	M1	Mixture 1	6.3 abc	5.0 b	6.0 bc	6.8 abc	6.2 abc	6.1 abc	6.5 ab	6.6 ab
	S1	Samar 1	6.8 bc	5.9 ab	6.0 bc	6.8 abc	5.5 bcd	6.5 ab	6.7 ab	6.5 abc
	Z1	Sidr 1	7.6 a	6.7 a	7.8 a	7.6 a	7.7 a	7.6 a	7.7 a	8.1 a
		Range	3.9~7.6	4.6~6.7	4.9~7.8	4.9~7.6	3.9~7.7	3.7~7.6	4.9~7.7	4.4~8.1

*Over-the counter product.
**Means, in each column, followed by the same letter are not significantly different (p > 5%).
***Hive collected product.

(II) *Sugar Composition*

Table 4 shows significant differences in the percentages of fructose, glucose, and sucrose. Fructose and glucose constituted the primary sugars in all honey samples. In honey of good quality, the percentage of fructose should exceed that of glucose. The fructose percentage ranged from 33.1% in Z1 and Z2 honey samples to 39.0% in AL honey. The percentage of glucose ranged from 25.6% in S2 honey to 37.3% in WE honey.

Trace amounts of sucrose were detected in most honey samples (Table 4), with the highest percentages found in Z2 (3.91%), DI (2.22%), AL (1.22%) and SB (1.08%), respectively. The percentage of sucrose in the remaining 17 honey samples ranged from 0.10% to 0.37%. Total sugars in the samples studied ranged from 64.9% (Z1) to 80.4% (Al) (Table 4).

Honey with a glucose content of 30% or more tends to granulate readily[5,23]. Samples with glucose to water ratios of 1.7 or less were considered non-granulating, while samples with ratios of 2.1 or more predicted rapid granulation[21,22,34,35]. Similarly, a glucose-water to fructose ratio higher than 0.50 predicted rapid granulation and a ratio lower than 0.20 predicted slow granulation[20,25]. A honey fructose to glucose ratio reaching 1.14 indicates a tendency to granulate more rapidly than a honey with a ratio significantly below 1.14[23,34,35]. Table 4 shows the granulation indices for 13 of the 21 honey samples.

It is generally believed that the higher the glucose content, the greater the tendency toward granulation. The percentage of glucose in our honey samples (n = 21) ranged from 25.6% to 37.3% (29.4~37.3% in the 13 selected samples). This relatively high range indicates that the honeys used in our survey are all fast granulating (Table 4). Considering glucose percentage only, samples S2, S3, Z2, Z3 (all hive-collected honeys) have, relative to other samples, lower granulation tendencies.

In terms of the glucose to water ratio (Table 4), DI (ratio: 1.74) and S1 (ratio: 1.80) are non-granulating honeys, UN (ratio: 2.0) and AL (ratio: 2.1) have lower granulation tendencies, and other samples have ratios that range from 2.15 to 2.72.

All samples had fructose to glucose ratios greater than 1. The 12 of out of our 21 honey samples with fructose to glucose ratios between 1.01 and 1.14 may be misleading as their data appears not to fit well with that in previously reported studies[4,25]. In our study, a sample with a fructose to glucose ratio greater-than-or-equal-to 1.0 indicated a tendency to granulate rapidly. However, as suggested by other researchers[25], the fructose to glucose ratio may not be the best indicator of granulation tendency.

In terms of the (glucose-water) to fructose ratio, DI, S1, UN, and AL indicated relatively low granulation tendencies, with ratios of 0.39, 0.40, 0.45, and 0.49, respectively. The glucose-water ratio corresponded relatively closely to glucose to water ratio results in terms of granulation tendency, with one significant exception. The 0.48 ratio for M1, indicating a tendency to granulate, ran contrary to other indices (fructose to glucose and glucose to water ratios). The remaining honey samples have ratios greater than 0.50

Table 4. Water content, sugar composition and granulation indices of *A. mellifera* local and imported honey

Product	Code	Honey brand	Water (W) (%)	Sugar composition (%)					Granulation indices			
				Fructose (F)	Glucose (G)	Sucrose (S)	Others	Total sugar	F / G	F – G	G / W	(G – W) / F
OTC	AL	Alalali	17.2* c	39.0 a	36.4 b	1.22 c	3.8	80.4	1.07	2.6	2.12	0.49
	BE	Bee Easy	13.1 j	38.1 bc	35.9 c	0.10 h	3	77.1	1.06	2.2	2.72	0.6
	DI	Diamond	19.8 a	37.6 de	34.4 d	2.22 b	3.1	77.3	1.09	3.2	1.74	0.39
	LA	Langnese BF	13.2 i	33.4 l	30.8 h	0.22 g	2.4	66.8	1.08	2.6	2.34	0.53
	NF	Nile Flower	—**	36.1 g	28.5 l	0.21 g	—	—	1.27	7.6	—	—
	SB	Sue Bee	14.3 f	37.1 e	37.2 a	1.08 d	2.8	76.9	1.03	1.2	2.5	0.62
	SA	Shifa Acacia	13.5 h	38.6 ab	33.9 e	0.20 g	2.5	75.2	1.14	4.7	2.5	0.53
	SL	Shifa Lime	15.4 e	34.1 k	33.1 f	0.21 g	2.9	70.3	1.03	1	2.15	0.52
	SO	Shifa Orange	14.2 g	37.7 cd	35.7 c	0.28 f	1.1	74.8	1.06	2	2.52	0.57
	UN	Unifood	16.3 d	36.8 e	32.9 f	0.37 e	5.3	75.4	1.12	3.9	2.01	0.45
	WE	Weabenecht	14.3 f	37.7 cd	37.3 a	0.20 g	1.9	77.1	1.01	0.4	2.61	0.61
HC	M1	Mixture 1	12.8 k	34.5 k	29.4 kj	0.23 fg	5.6	69.7	1.17	5.1	2.31	0.48
	M2	Mixture 2	—	37.1 e	29.3 kl	0.23 fg	—	—	1.27	7.8	—	—
	M3	Mixture 3	—	37.1 e	30.1 i	0.20 g	—	—	1.23	7	—	—
	M4	Mixture 4	—	35.6 hi	28.1 n	0.21 g	—	—	1.27	7.5	—	—
	S1	Samar 1	17.7 b	35.8 gh	31.9 j	0.22 fg	2.5	70.4	1.12	3.9	1.8	0.4
	S2	Samar 2	—	35.6 hi	25.6 o	0.21 g	—	—	1.39	10	—	—
	S3	Samar 3	—	35.3 j	26.3 n	0.21 g	—	—	1.34	9	—	—
	Z1	Sidr 1	11.1 l	33.1 l	29.6 k	0.21 g	2	64.9	1.12	3.5	2.66	0.56
	Z2	Sidr 2	—	33.1 l	25.8 o	3.91 a	—	—	1.28	7.3	—	—
	Z3	Sidr 3	—	34.2 k	26.1 n	0.23 fg	—	—	1.31	8.1	—	—

*Means, in each column, followed by the same letter are not significantly different ($p > 0.05$).

**No analysis was made.

(range: 0.52~0.62).

The larger the difference is between the percentages of fructose and glucose in honey, the lower the granulation tendency. Differences in fructose and glucose contents in our samples ranged from 0.4% (WE) to 10.0% (S2). Differences were much higher in most of the hive-collected samples (M1-3, S1-3, Z1-3) than in the samples purchased on the retail market (Table 4).

Analyzing the relationship between granulation and indices type suggests that the fructose to glucose ratio may not be an effective gauge of granulation tendency. While glucose percentage is a useful indicator of honey granulation, the glucose to water ratio appears to be one of the most effective indicators predicting granulation in honey. The glucose to water ratio may be used both to predict and control granulation tendencies. Our work suggests that the analytical work required to measure glucose concentration and then adjust the water content to a level that retards the granulation is minimal and relatively easy to accomplish[4,11].

In terms of consumer appeal, granulated honey (i.e., honey in a semi-solid state) is generally regarded as unacceptable. When granulation is incomplete, the crystalline layer is overlaid by a layer of liquid honey with a water content that is higher than that in the original honey. This creates a favorable environment for yeast growth and may lead to fermentation. Therefore, the granulation process should be avoided through proper storage practices that maintain optimal storage temperatures.

Table 5. Total protein and pH values of *A. mellifera* local and imported honey samples

Product	Code	Honey trade name	Total protein (%)	pH
OTC	AL	Alalali	0.239* f	3.65 k
	BE	Bee Easy	0.203 g	3.94 g
	DI	Diamond	0.191 i	3.86 i
	LA	Langnese BF	0.376 c	4.10 e
	SB	Sue Bee	0.033 m	3.87 h
	SL	Shifa Lime	0.108 k	4.42 c
	SO	Shifa Orange	0.156 j	3.60 m
	UN	Unifood	0.193 h	4.05 f
	WE	Weabenecht	0.296 e	3.62 l
HC	M1	Mixture 1	0.094 l	4.22 d
	S1	Samar 1	0.731 a	4.44 b
	Z1	Sidr 1	0.374 d	5.72 a
	Average		0.277	4.1
	Range		0.033~0.731	3.60~5.72

*Means, in each column, followed by the same letter are not significantly different ($p > 0.05$).

(III) *Total Protein*

Total protein content in honey averages about 0.17% of weight, but can vary widely (between 0.02% and 1.0%)[11,20,35]. Table 5 shows the significant differences among our samples in terms of protein content. Percentage of total protein ranged from 0.033% in SB to 0.731% in S1. S1, Z1, SF, and WE contained higher percentages of total protein than other samples. Trace amounts of protein were found in SB, M1, and SL.

Table 6. Concentration of mineral elements (mg/L) in *A. mellifera* local and imported honey samples

Product	Code	Honey trade name	Major elements							Trace elements		
			Na	K	Mg	Ca	P	Fe	Zn	Cu	Mn	Co
OTC	AL	Alalali	417.6* gh	273.5 s	—**	—	—	14.7 h	—	1.55 b	0*** k	—
	BE	Bee Easy	438.8 f	702.9 o	—	—	—	9.9 i	—	0.43 n	0.11 jk	—
	DI	Diamond	542.0 d	627.9 p	—	—	—	53.9 a	—	1.07 q	1.12 e	—
	LA	Langnese BF	463.5 e	5340.9 a	128.9 c	24.9 h	211.7 c	8.1 j	11.1 c	2.31 a	12.8 a	0.088 b
	NF	Nile Flower	11.2 lm	3377.9 c	54.5 g	50.5 e	31.5 i	40.0 b	3.1 def	1.10 e	3.33 b	0.041 d
	SA	Shifa Acacia	463.5 e	3120.1 g	—	—	—	5.6 k	—	0.57 i	0 k	—
	SL	Shifa Lime	666.5 a	1041.5 m	35.7 i	12.4 i	38.6 h	4.0 l	8.7 cd	0.31 p	1.37 d	0.037 f
	SO	Shifa Orange	489.2 b	396.6 h	—	—	—	0 m	—	0.30 p	0 k	—
	SU	Sue Bee	445.6 f	562.1 q	31.6 j	2.2 j	27.3 j	18.9 f	1.6 f	0.39 o	0.44 h	0.028 h
	UN	Unifood	577.8 c	382.7 s	—	—	—	0 m	—	0 s	0 k	—
	WE	Weabenecht	429.9 fg	451.7 r	—	—	—	36.5 d	—	0 s	0 k	—
HC	M1	Mixture 1	446.5 f	1646.2 j	—	—	—	0 m	—	0.31 p	0 k	—
	M2	Mixture 2	170.6 j	2067.2 g	104.2 f	109.2 c	95.6 e	5.9 k	7.3 cde	0.55 j	0.42 i	0.036 g
	M3	Mixture 3	167.2 j	1615.2 j	124.0 d	512.1 a	158.6 d	40.4 b	4.6 def	1.15 d	1.86 c	0.092 a
	M4	Mixture 4	231.9 h	1396.0 l	107.7 e	114.0 b	81.6 f	8.0 j	19.2 b	0.52 l	0.43 hi	0.053 c
	S1	Samar 1	401.7 h	1527.1 k	—	—	—	0 m	—	1.47 c	0 k	—
	S2	Samar 2	161.3 j	3831.0 b	168.6 a	99.5 d	261.6 b	22.9 e	23.2 b	1.00 f	0.85 f	0.034 e
	S3	Samar 3	172.9 j	2614.7 e	150.9 b	35.6 g	306.7 a	38.6 c	41.7 a	0.76 g	0.57 g	0.037f
	Z1	Sidir 1	446.6 f	1719.2 h	—	—	—	14.6 h	—	0.03 r	0 k	—
	Z2	Sidir 2	0.2 m	2453.7 f	23.6 k	0.01 k	22.5 k	5.1 k	1.9 ef	0.45 m	0.23 j	0.045 i
	Z3	Sidir 3	43.4 k	3007.2 d	41.4 h	41.5 f	42.8 g	16.3 g	12.7 c	0.62 h	0.43 i	0.028 h

*Means, in each column, followed by the same letter are not significantly different ($p > 0.05$, n = 6).

** No analysis was made.

*** Undetectable element in the sample.

(IV) *pH Values*

Table 5 shows significant differences among honey samples in terms of pH value. Sample pH values ranged from 5.72 in Z1 to 3.60 in SO.

(V) *Mineral Elements*

We found significant differences ($p < 0.05$) in the quantity of four trace elements in our samples (Table 6). While copper was not detected in UN and WE samples, other samples contained concentrations ranging from 0.03 (Z1 honey) and 2.31 mg/L (AL honey). The concentration of cobalt ranged between 0.028 (SU and Z3) to 0.092 mg/L (M3). Manganese was not present in AL, M1, S1, SA, SO, UN, WE, and Z1, but was found in concentrations ranging from 0.11 (BE) to 12.8 mg/L (LA) in the other samples. Chromium content ranged from 0.19 (Z2) to 0.75 mg/L (NF). Our findings with regard to trace elements were in accordance with other published findings[5,6,8,10,11,24,36], in which these elements were either undetected or below maximum recommended amounts.

We identified highly significant differences ($p < 0.05$) in the quantity of seven major elements in all samples (Table 6). Sodium concentrations ranged from 0.2 (Z2) to 666.5 mg/L (SL). The concentrations of potassium exceeded that of sodium in most samples, ranging from 273.5 (AL) to 5340.9 mg/L (LA). The concentration of magnesium ranged from 23.6 (Z2) to 168.6 mg/L (S2); calcium from 0.01 (Z2) to 512.1 mg/L (M3); and phosphorus from 22.5 (Z2) to 306.7 mg/L (S3). Iron was undetectable in M1, S1, and SO and found in other samples in concentrations from 4.0 (SL) to 53.9 mg/L (DI). Finally, the concentration of zinc ranged from 1.6 (SB) to 41.7 mg/L (S3). Concentrations of these major elements in our samples corresponded relatively closely to the results reported in studies done on honey samples from Turkey, Spain, Italy, Slovenia, and the Czech Republic[7-9,12,13,16,32].

CONCLUSIONS

Good correlation was found between sensory evaluation and chemical analysis of honey samples. Analysis of sensory characteristics showed that samples collected directly from the hive had higher overall acceptance scores than those for over-the-counter honey samples. The results reported in this study may help industry and researchers better understand honey properties and the impact of these properties on consumer preference. Understanding key sensory evaluation criteria and the composition of honey through physico-chemical analysis is important to the honey industry, as these factors are intimately related to storage quality, granulation, texture, flavor, and the nutritional and medicinal qualities of honey.

The Gulf Area is now re-evaluating the importance of alternative medicines obtained from natural sources and honey is regaining recognition for its medicinal effects. Increasing problems related to adulteration and otherwise tampering with natural honeys sold on retail markets encouraged us to conduct this evaluation of domestic and imported honeys available in the UAE. This study summarizes the present state of knowledge on the quality of honey brands sold or produced in the Arab Gulf countries and the quality factors which should be used in the upgrading of honey regulations to define and control honey quality. We understand that the stated quality factors do not completely satisfy the quality standards required by all countries. Therefore, research on honeys available in Arab Gulf countries should expand in order to better understand product properties and underscore medical and nutritional values.

ACKNOWLEDGEMENTS

We would like to thank A. A. Al-Jasmi and S. S. Al-Minhali for their technical assistance in the analysis of sugar and mineral elements.

REFERENCES

1. Albore, R. 1994. Characterization of honeys from the Veneto region by quality and geographical origin. Annali della Faoolta di Agraria, Universita degli Studi di Perugia 48: 457-492.
2. Al-Naji, L. K. and Hujazy, I. M. 1982. Microorganisms of ripe honey produced in northern Iraq and their effects on its physical properties. Zanco (Iraq) 8: 3-16.
3. Aparna, A. R. and Rajalakshmi, D. 1999. Honey – its characteristics, sensory aspects and applications. Food Rev. Internat. 15: 455-471.
4. Austin, G. H. 1953. Maintaining a high quality in liquid and recrystallized honey. Can. Bee J. 61: 4-10.
5. Bogdanov, S. 1993. Liquefaction of honey. Apiacta XXVIII: 4-10.
6. Bogdanov, S. 1999. Honey quality and international regulatory standards: Review by the International Honey Commission. Bee World 80: 61-69.
7. Bogdanov, S., Lullman, C. and Martin, P. 1999. Honey quality and international regulatory standards. Review of the work of the International Honey Commission. Mitt. Gebiete Lebensm. Hyg. 90: 108-125.
8. Bogdanov, S., Martin, P. and Lullman, C. 1997. Methods in agreement with the European Honey Commission. Apidologie. Extra issue. p. 59.
9. Bonvehl, J. S. and Coli, F. V. 1993. Physico-chemical properties, composition and pollen spectrum of French lavender (*Lavandula stoechas* L.) honey produced in Spain. Z. Lebnesm-Unters-Forsch 196: 511-517.
10. Caroli, S., Forte, G., Iamiceli, A. L. and Galoppi, B. 1999. Determination essential and potentially toxic trace elements in honey by ICP. Talanta 50: 327-336.

11. Celechovoska, O. and Vorlova, L. 2001. Groups of honey-physicochemical properties and heavy metals. Acta Vet. Brno 70: 91-95.
12. Crane, E. 1990. Bees and Beekeeping. p. 614. Bath Press Ltd. Avon.
13. Crane, E., Penelope, W. and Rosemary, D. 1984. Directory of Important World Honey Sources. International Bee Research Association.
14. Esti, M., Panfili, G., Marconi, E. and Trivisonno, M. C. 1997. Valorization of the honeys from the Molise region through physicochemical, organoleptic and nutritional assessment. Food Chem. 58: 125-128.
15. Estupinan, S., Sanjuan, E., Millan, R. and Gonzalez Cortes, M. A. 1998. Quality parameters of honey. II. Chemical composition. A review. Alimentaria 297: 117-122.
16. Golob, T. and Plestenjak, A. 1999. Quality of slovene honey. Food Tech. Biotech. 37: 195-201.
17. Gupta, J. K., Kaushik, R. and Joshi, V. K. 1992. Influence of different treatments, storage temperature and period on some physico-chemical characterization and sensory qualities of Indian honey. J. Food Sci. Tech. 29: 84-87.
18. Hankin, L. 1987. Analysis of honey. Bulletin, Connecticut Agricultural Experiment Station 847: 6.
19. Hussein, M. H. 2000. A review of beekeeping in Arab countries. Bee World 81: 56-71.
20. Jackson, R. S. and Silsbee, C. G. 1924. Saturation relations in mixtures of sucrose, dextrose and levulose. In “Standards Bureau Technol”. pp. 259-304. U.S. Commerce Dept. U. S. A.
21. Jamieson, C. A. 1954. Some factors influencing the crystallization of honey. Rep. La St. Apiar. pp. 64-37. Apic. Abstracts 64/58 (1954).
22. Kohlich, A., Hoffmann, C. and Mossbeckhofer, R. 1995. Chemical and physical analysis of honeys of different origins for the drawing up of characteristic values for honey evaluation. Bienenvater 116: 420-426.
23. Koudounis, M. I. 1962. The crystallization of honey. Ph. D. Thesis. Athens, University of Athens, Ministry of Agriculture. p. 88.
24. Kump, P., Necemer, M. and Snajder, J. 1996. Determination of trace elements in bee honey, pollen and tissue by total reflection and radioisotope X-ray fluorescene spectrometry. Spectrochim. Acta B 51: 499-507.
25. Manikis, I. and Thrasivoulou, A. 2001. The relation of physicochemical characteristics of honey and the crystallization sensitive parameters. Apiacta 36: 106-112.
26. Natarajan, R. and Yesuvadian, M. S. 1978. Project report for a honey concentration equipment. Indian Honey 1: 15-21.
27. Qiu, P. Y., Ding, H. B., Tang, Y. K. and Xu, R. J. 1999. Determination of chemical composition of commercial honey by near infrared spectroscopy. J. Agric. Food Chem. 47: 2760-2765.
28. Russmann, H. 1998. Yeasts and glycerol in blossom honey detection of fermentation or stopped fermentation. Lebensmittelche-mie 52: 116-117.
29. Sanjuan, E., Estupinan, S. and Millan, R. 1997. Contribution to the evaluation and the water activity prediction of La Palma island honey. J. Food Qual. 20: 225-234.
30. Sanz, S., Gradillas, G., Jimeno, F., Perez, C. and Juan, T. 1995. Fermentation problem in Spanish north-coast honey. J. Food Prot. 58: 15-518.
31. SAS Institute. 1990. SAS/STAT User’s Guide. Vol. 1 and 2. Gary, North Carolina, U. S. A.
32. Singh, N. and Kuar Bath, P. 1997. Quality evaluation of different types of Indian honey. Food Chem. 58: 129-133.
33. Taschan, H., Puchtinger, T. and Muskat, E. 1994. Comparison of quality of honeys of various commercial types. Verbraucherdienst 39: 147-155.
34. White, J. W. 1975. Physical characteristics of honey. In “Honey A Comprehensive Survey”. p. 608. Crane, E. ed. Heinemann. London, U. K.
35. White, J. W., Riethot, M. L., Subers, M. H. and Kushir, I. 1962. Composition of American honeys. Technical Bulletin, U.S.D.A. No. 1261. p. 124.
36. Yilmaz, H. and Yavuz, O. 1999. Content of some trace metals in honey from South-eastern Anatolia. Food Chem. 65: 475-476.