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Physicochemical characteristics, total phenols and pigments of national and international honeys in Saudi Arabia

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Abstract In 23 types of honey from Saudi Arabia and six other countries, the levels of some minor components and floral pigments as well as physicochemical characteristics were investigated. Most tested Saudi honeys, *e.g.* Acacia and Seder showed high values of density and total soluble solids and low water content compared to exotic ones. Some Acacia and Manuka samples had higher HMF contents than permitted levels. All the tested honeys were acidic; however Acacia honey had total acidity values over those of permitted levels, while most of the remainding types were comparable or acceptable. Also, Saudi Acacia and Egyptian honeys contained more content of total nitrogen, free amino acids and proline than those of the other tested types. Dark-colored honeys *e.g.* Acacia contained more phenolic content than those of the light-colored ones. Carotenoids were the predominant floral pigments in all the tested honeys, while xanthophylls and anthocyanins were the least predominant ones. Seder honeys showed moderate values of the tested characteristics compared to other types. The tested parameters are useful to determine the botanical origin of Saudi or exotic honeys and their quality. Further research on specific physicochemical properties of Saudi Acacia honey especially acidity is very much recommended. New criteria based on the regional characteristics of Saudi honeys including antioxidants, micro-constituents are suggested.

1. Introduction

Determination of the standard criteria of food products is the most important process, since consumption, quality and validity of these products depend on it. Also, purity and contaminant-free food are other factors of great concern for consumer health. Honey is one of the most important global natural products. Honey comes in the first order of these products, since it has many benefits in foods, and medicine. Honey, generally contains, on average, water (20%), monosaccharides

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(75% fructose and glucose), disaccharides (3–10% sucrose), complex sugars and other materials, *e.g.* proteins, vitamins, enzymes and minerals (Celechovska, 2002 and Serrano et al., 2007). Honey also contains important components *e.g.* antioxidants (Berettaa et al., 2005; Baltac et al., 2006 and Bertoncelj et al., 2007). Some reports mentioned that honey contains more than 200 components (Kucuk et al., 2007). Since honey types differ from one country to another and in different regions in the same country due to floral origin, soil composition and other factors consequently, quality criteria differ from one honey type to another, *i.e.* blossom honey is greatly different than the honeydew one. So these criteria vary according to these factors and need to be periodically revised with updating methodologies, as local and global standards change, *e.g.* the permitted level of hydroxymethylfurfural (a toxic material produced in overheating and/or long storage of honey) was formerly 40 mg/kg, this level was suggested to be 60 mg/kg (CAC, 1998).

In Arab countries honey has the first rank in folk medicine. In Saudi Arabia, the consumption of honey is increasing, since it is one of the principle ingredients in foods, as remedy and in natural mixtures (Alqarni, 2011). There are many types of honey (local and exotic) commonly consumed in Saudi Arabia. Most of these honeys are traded without quality sign or reference to their origins and this may lead to honey adulteration and/or marketing non-standard honeys. So, comparing these honeys with quality standards is greatly required. Also, some preliminary reports mentioned that Saudi Acacia honey has over permitted acidity levels. This suggestion needs to be explained (Alqarni, unpublished data).

Although, previous studies which were conducted on Saudi honeys focused on physiochemical characteristics, minerals content, pollen spectrum, and antimicrobial activity (Mesallam and El-Shaarawy, 1987; Abu-Tarboush et al., 1992; Al-Khalifa and Al-Arify, 1999; Al-Doghairi et al., 2007; Ashraf and Akram, 2008), they did not deal with other important constituents. In this study we determined some minor constituents of Saudi and exotic honeys, *i.e.* floral pigments, proline, total amino acids and total phenolic contents. We propose these measurements as "chemometrics" or markers of quality criteria for Saudi and exotic honeys, as well as ordinary characteristics listed in the national and international standards.

2. Experimental

Native and exotic honeys (23 samples from Saudi Arabia and 6 countries) were tested. Thirteen samples were collected from local honey producers at different regions of Saudi Arabia (11 samples are floral and 2 from artificially-fed colonies). Out of the exotic samples, 3 were from Egypt, 2 from New

Table 1 Types and regional data of the 23 tested honey samples.

Codes*	Honey types (Scientific names)	Area of production and year
ACS1	Acacia Saudi Honey 1 (*Acacia* spp.)	South KSA (Stored honey)
ACS2	Acacia Saudi Honey 2 (*A.* spp.)	Middle KSA 2009
ACS3	Acacia Saudi Honey 3 (*A.* spp.)	Shouaib Al-sahl, KSA 2009
SMS	Somrah (*A. tortalis*)	Al-Taif, Southwestern KSA (Stored honey)
SDS1	Seder (*Ziziphus spina-christi*)	South KSA 2009
SDS2	Seder (*Z. spina-christi*)	Rawdha Al-Hashim, KSA 2009
SDS3	Seder (*Z. spina-christi*)	Al-Taif, Southwestern KSA 2009
SHS	Shefallah (*Capparis* spp.)	Shouaib Tarif, KSA 2010
ALS	Alfalfa (*Medicago sativa*)	Al-Ghowailk farm, KSA 2010
MFS1	Multifloral (various flowers)	Diyrab[e], South Riyadh, KSA 2010
MFS2	Multifloral (various flowers)	Diyrab, South Riyadh, KSA (Stored honey)
ARS1	Artificially-fed colonies[a]	Diriyah, BRU[d], Riyadh, KSA 2010
ARS2	Artificially-fed colonies[b]	Diriyah, BRU, Riyadh, KSA 2010
SDY	Seder (*Z. spina-christi*)	Hadramout, Yemen 2009
CTE	Citrus (*Citrus* spp.)	Qalibubia governorate, Egypt 2010
CVE	Clover (*Trifolium alexnadrinum*)	Fayoum gov., Egypt 2010
CNE	Cotton (*Gossypium barbadense*)	Fayoum gov.,Egypt 2010
MKN1	Manuka UMF[c] 18% (*Leptospermum* spp.)	New Zealand 2009
MKN2	Manuka UMF 10% (*L.* spp.)	New Zealand 2009
BFG	Black Forest (forest trees)	Germany 2009
PAG	Pseudoacacia (*Rhobinia pseudoacacia*)	Germany 2009
JRA	Jarrah (*Eucalyptus marginata*)	Australia 2009
TUM	Tualang (*Koompassia excels*)	Malaysia 2009

[a] *A. m. yemenitica* colonies.
[b] *A. m. carnica* colonies.
[c] unique manuka factor.
[d] Bee Research Unit, King Saud University, KSA.
[e] Educational Farm of College of Food and Agric. Sci., KSU, KSA.
* ACS1,2,3 (*Acacia gerardii* honey from 3 locations, KSA), BFG (Black forest honey, Germany), SMS (*Acacia tortilis* honey, KSA), MKN 1&2 (Manuka honey 18% and 10% UFM, New Zealand), MFS 1&2 (Multifloral honeys 1&2, KSA) SHS (Shafallah- caper bush- honey, *Capparis spinosa*, KSA), SDS1,2,3 (Seder, *Ziziphus* sp. honey from 3 locations, KSA), SDY (Seder, *Z. sp.* honey, Yemen), TUM (Tualang tree Koompassia excelsa honey, Malaysia), CNE (Cotton honey, Egypt), JRA (Jarrah, Eucalyptus marginata honey, Australia), CVE (Clover honey, Egypt), PAG (Pseudoacacia trees, Robinia pseudoacacia honey, Germany), ARS 1&2 (Artificially fed colonies honey 1&2, KSA), CTE (Citrus honey, Egypt), and ALS (Alfalfa honey, KSA).

Zealand, 2 from Germany, and 1 each from Yemen, Australia and Malaysia. All the tested honeys were produced by *Apis mellifera* except the Malaysian one that was produced by *A. dorsata*. Common names of these honeys, years of production and regional data are shown in Table 1. All samples were packed in glass bottles (250gm/ honey type) and kept at room temperature (*ca*. 25°C) away from light until analysis.

The tested parameters were determined in the College of Food and Agriculture Sciences, King Saud University, Riyadh, Saudi Arabia, during June, 2010.

Abbe's refractometer was used to determine the refractive index, density and total soluble solids. Honey samples were analyzed according to the methods of AOAC (2000) as follows: water content was obtained after temperature correction of the reading. The pH was measured using a pH-meter. Free acidity; lactone and total acidity were determined by the titrimetric method; HMF content was determined by the UV spectrometric method (White, 1979); nitrogen content according to Hafez and Mikkelsen (1981); total free amino acids following Jayarman (1981); proline content after Bates et al. (1973) and total phenols as described by Snell and Snell (1953).

Tested pigments were colorimetrically determined using spectrometric methods: total anthocyanins following Fuleki and Francis (1968); chlorophylls and xanthophylls according to the modification given by Bacot (1954) and carotenoids after the equations given by Aron (1949). Pigment contents were expressed as μg/g fresh weight of the honey sample. Three replicate samples of each honey type were analyzed for any determination.

Data were assessed by analysis of variance (ANOVA) according to Snedecor and Cochran, 1967) and by Duncan's test with probability $p \leqslant 0.05$.

3. Results and discussion

Data in Table 2 show average values of physicochemical characteristics determined in the tested Saudi and exotic honeys. The values of refractive index (RI) ranged between 1.4685 and 1.5067 in the tested samples. Saudi multifloral (MFS1) and artificially-fed honeys (ARS2) showed the highest RI values, while the lowest one was for Malaysian Tualang honey (TUM) with significant differences between values. Some Saudi samples, *e.g*. Seder (SDS1), Acacia (ACS1) and Somrah (SMS) had also relatively high RI values, while most exotic honeys had lesser ones. The same trend was noticed for density. These present findings agree with those reported by Youssef and El-Gadawy (1973), Al-khalifa and Al-Arify (1999) and fell within those standardized for American honey.

Total soluble solids (TSS) ranged between 70.0% (TUM) and 85.0% (MFS1) with significant difference between the two values. Noticeably, the samples with high density values had high TSS contents (Table 2). All tested Saudi honeys showed higher TSS values than those of exotic ones.

Table 2 Mean values of some physicochemical properties of 23 honey samples produced in Saudi Arabia and 6 other countries.

Code	RI value	Density value	TSS (%)	Water content (%)	HMF (mg/kg)	pH value	Free acidity (meq/kg)	Lactone (meq/kg)	Total acidity (meq/kg)
ACS1	1.4957d	1.4164d	81.0cd	16.52gh	168.97c	4.18c	120.5b	10.0bc	130.5b
ACS2	1.4937f	1.4115f	80.0d	17.32f	101.80e	4.18c	134.5a	11.0ab	145.5a
ACS3	1.4937f	1.4115f	80.0d	17.32f	26.05l	4.46b	112.0c	7.5de	119.5c
SMS	1.4957d	1.4164d	81.0cd	16.52gh	229.6b	3.48fg	50.0e	5.0fgh	55.5f
SDS1	1.4999c	1.4265c	82.5bc	14.84i	31.55j	4.13c	28.0h	5.0fgh	33.0h
SDS2	1.4937f	1.4115f	80.0d	17.32f	20.70o	4.66ab	19.5jk	5.0fgh	24.5i
SDS3	1.4947e	1.4139e	80.5cd	16.92fg	12.05s	4.73a	18.5jkl	5.0fgh	23.5ij
SHS	1.4937f	1.4115f	80.0d	17.32f	22.75n	3.33fgh	29.5gh	2.5i	32.0h
ALS	1.4947e	1.4139e	80.5cd	16.92fg	14.07r	3.09hi	17.0lmn	7.5de	24.5i
MFS1	1.5067a	1.4429a	85.0a	12.12k	21.30o	3.47fg	18.0klm	5.0fgh	23.0ijk
MFS2	1.4999c	1.4265c	82.5bc	14.84i	258.72a	3.24fghi	20.0j	5.0fgh	25.0i
ARS1	1.4999c	1.4265c	82.5bc	14.84i	16.43q	3.15hi	17.0lmn	7.5de	24.5i
ARS2	1.5040b	1.4364b	84.0ab	13.20j	10.09t	3.31fghi	12.0o	6.0efg	18.0m
SDY	1.4937f	1.4115f	80.0d	17.32f	39.48h	4.07cd	17.0lmn	3.5hi	20.5klm
CTE	1.4867h	1.3945h	77.5ef	20.12d	23.77m	3.30fghi	16.5mn	5.0fgh	21.5jkl
CVE	1.4867h	1.3945h	77.5ef	20.12d	2.21u	3.23fghi	15.5n	5.0fgh	20.5klm
CNE	1.4867h	1.3945h	77.5ef	20.12d	14.63r	3.21ghi	49.5e	9.0bcd	58.5e
MKN1	1.4745j	1.3646j	72.5g	25.00b	87.72f	3.51f	31.0g	8.0cde	39.0g
MKN2	1.4907g	1.4042g	79.0de	18.52e	129.98d	3.23fghi	34.5f	4.0ghi	38.5g
BFG	1.4907g	1.4042g	79.0de	18.52e	35.74i	3.90de	49.5e	7.0def	56.5ef
PAG	1.4828i	1.3849i	76.0f	21.68c	29.19k	3.27fghi	16.5mn	2.5i	19.0lm
JRA	1.4867h	1.3945h	77.5ef	20.12d	17.70p	4.02cde	23.5i	7.5de	31.0h
TUM	1.4685k	1.3498k	70.0h	27.40a	51.31g	3.03i	72.0d	12.5a	84.5d

Values with varied letters differed significantly at 5%.

*ACS1,2,3 (*Acacia gerardii* honey from 3 locations, KSA), BFG (Black forest honey, Germany), SMS (*Acacia tortilis* honey, KSA), MKN 1&2 (Manuka honey 18% and 10% UFM, New Zealand), MFS 1&2 (Multifloral honeys 1&2, KSA) SHS (Shafallah-caper bush-honey, *Capparis spinosa*, KSA), SDS1,2,3 (Seder, *Ziziphus sp*. honey from 3 locations, KSA), SDY (Seder, *Z. sp*. honey, Yemen), TUM (Tualang tree Koompassia excelsa honey, Malaysia), CNE (Cotton honey, Egypt), JRA (Jarrah, Eucalyptus marginata honey, Australia), CVE (Clover honey, Egypt), PAG (Pseudoacacia trees, Robinia pseudoacacia honey, Germany), ARS 1&2 (Artificially fed colonies honey 1&2, KSA), CTE (Citrus honey, Egypt), and ALS (Alfalfa honey, KSA).

Extraordinarily, Egyptian tested honeys had the same TSS values (77.5%). Water contents ranged between 12.12% for MFS1 and 27.40% for TUM with significant difference between the two values. Also, MKN1 had high water content (25.00%). All the tested Saudi honeys had relatively low water content (12.12%–17.32%) compared to exotic or Egyptian honeys which showed high water content (20.12%). Also, Saudi multifloral or artificially-fed honeys had the least water content ranging between 12.12%–14.84%. Most of present water content values agree with those found by Abu-Tarboush et al. (1992) for sugar-fed honey and with those of Mesallam and EL-Shaarawy (1987): range 13.8%–15.6%; Kaakeh and Gadelhak (2005): range 11.1%–19.8% for local and imported honeys in the Arab Gulf region and Al-Doghairi et al. (2007): range 13.0%–16.8% for Saudi honeys. They attributed this low level to the dry weather in the area of honey production. There was an obvious inverse relation between TSS and water content in all tested samples (Table 2). Water content in honey is responsible for its stability against fermentation and granulation. Normally ripe honey has a moisture content below 18.6% (Bogdanov et al., 1999). Moisture content was higher (21.5%) in *A. dorsata* honey than that (17.1%) of *A. mellifera* one (Joshi et al., 2000). While national beekeeping organizations in some countries (*e.g.* Germany, Belgium, Austria, Italy and Switzerland) have a maximum of 18%–18.5%, the European Union suggests a maximum value of 21% moisture content (Codex Alimentarious Commission, 1998).

Data in Table 2 indicate that 4 Saudi honeys (ACS1, ACS2, SMS & MFS2) and 2 exotic ones (MKN1 & MKN) had very high HMF content being 168.97 mg/kg, 101.80 mg/kg, 229.60 mg/kg & 258.72 mg/kg, and 87.72 mg/kg & 129.98 mg/kg, respectively with significant differences between values. So these 6 honey types are considered as "Stored or over-heated" honeys. The remaining samples had acceptable HMF values ranged between 2.21 mg/kg for CTE and 51.31 mg/kg for TUM. The HMF level is a major quality factor in honey. Fresh honeys have no HMF content, but it increases depending on honey pH and storage temperature. Some European federations permit a maximum of 15 mg/kg HMF for "quality honey". In international trade this maximum is 40 mg/kg (Codex Alimentarious Commission, 1993). On the other hand, an amount of 10 mg/kg HMF in honey is naturally present, but a large increase of content could be due to overheating or to adulteration (Crane, 1980). Recently, the maximum proposed value of HMF by the Codex is 60 mg/kg (Codex Alimentarious Commission, 1998). Honey produced in subtropical climates has high HMF value exceeding 40 ppm (La Grange and Sanders, 1988). High HMF values for Saudi Acacia honey were reported by Al-khalifa and Al-Arify (1999), but their values fell within the Saudi standards.

The pH values of the tested honeys were acidic and relatively close, ranging between 3.03 for TUM and 4.73 for SDS3 honeys with significant difference between the two values. Acacia and Seder honeys exhibited relatively higher pH values than those of the other tested types (Table 2). The pH value in honey is not directly related to free acidity because of the buffering action of various acids and minerals present. The pH of honey varied from 3.42 to 6.10 (White, 1978). High pH value (6.23) was reported for Sidir Aseer honey, while Sidir Albaha had a pH of 3.93 (Al-khalifa and Al-Arify, 1999). Al-Doghairi et al. (2007) recorded 3.51–5.27 pH values for Saudi honeys. The pH is a useful criteria of possible microbial growth. Most bacteria grow in a neutral and mildly alkaline media, while yeasts and molds grow in acidic ones (Conti et al., 1998). Also, pH is used for discrimination between honeydew (high pH values) and blossom honeys (low ones).

Free acidity ranged between 12.0–134.5 meq/kg. Acacia, Somrah (stored or fresh), cotton, Black Forest and Tualang honeys had higher values compared with other types. The same trend was relatively noticed for lactone contents (Table 2). Total acidity was also high in the same types ranging between 55.5 meq/kg (SMS) and 145.5 meq/kg (ACS2) with significant difference between the two values. These findings are much higher than the maximum standard (40 meq/kg) which has been proposed to 50 meq/kg in the Codex draft, since some honeys have a higher natural acidity. Tested Seder and Egyptian honeys had moderate total acidity values, while the remaining types showed acceptable values ranging between 18.0 meq/kg (ARS2) and 39.0 meq/kg (MKN1) (Table 2). Total acidity indicates the history of honey and possible alcohol and acid production by bacterial fermentation (Rodgers, 1979). Al-khalifa and Al-Arify (1999) showed that acidity values did not differ significantly between Sidir and Talh (Acacia) honeys. Al-Doghairi et al. (2007) found a wide range of total

Table 3 Nitrogen, total free amino acids, proline and total phenols contents (mg/g honey in 23 honey samples produced in Saudi Arabia and six other countries.

Code	N	T. amino acids	Proline	Total phenols
ACS1	4.90ab	1.94ef	1.30c	0.74b
ACS2	4.98ab	1.98ef	1.25cd	0.80a
ACS3	4.78ab	1.89f	1.16cd	0.84a
SMS	3.28cd	1.96ef	1.24cd	0.81a
SDS1	4.00bc	2.12de	1.46b	0.68cd
SDS2	3.79cd	1.98ef	1.45b	0.70bc
SDS3	4.12bc	2.38c	1.49b	0.66cd
SHS	3.48cd	1.99ef	1.40bc	0.76b
ALS	5.54a	2.84a	1.80a	0.49fg
MFS1	4.68ab	2.69b	1.70a	0.51e
MFS2	4.92ab	2.45c	1.60b	0.60cd
ARS1	5.29a	2.71b	1.70a	0.50ef
ARS2	4.48bc	2.68b	1.64b	0.56cde
SDY	4.90ab	2.40c	1.56b	0.61cd
CTE	5.10a	2.84a	1.78a	0.44g
CVE	5.69a	2.99a	1.83a	0.46fg
CNE	4.04bc	2.62b	1.68b	0.59cd
MKN1	4.69ab	2.64b	1.60b	0.58cde
MKN2	4.51b	1.89f	1.14d	0.84a
BFG	4.20bc	2.28cd	1.46b	0.66cd
PAG	5.61a	2.98a	1.88a	0.42gh
JRA	4.08bc	2.31c	1.47b	0.64cd
TUM	3.81cd	1.94ef	1.21cd	0.80a

Values with varied letters differed significantly at 5%.
*ACS1,2,3 (*Acacia gerardii* honey from 3 locations, KSA), BFG (Black forest honey, Germany), SMS (*Acacia tortilis* honey, KSA), MKN 1&2 (Manuka honey 18% and 10% UFM, New Zealand), MFS 1&2 (Multifloral honeys 1&2, KSA) SHS (Shafallah- caper bush- honey, *Capparis spinosa*, KSA), SDS1,2,3 (Seder, *Ziziphus sp.* honey from 3 locations, KSA), SDY (Seder, *Z. sp.* honey, Yemen), TUM (Tualang tree Koompassia excelsa honey, Malaysia), CNE (Cotton honey, Egypt), JRA (Jarrah, Eucalyptus marginata honey, Australia), CVE (Clover honey, Egypt), PAG (Pseudoacacia trees, Robinia pseudoacacia honey, Germany), ARS 1&2 (Artificially fed colonies honey 1&2, KSA), CTE (Citrus honey, Egypt), and ALS (Alfalfa honey, KSA).

acidity between 9.12–93.02 meq/kg for Saudi honeys. The acidity of honey might be due to the presence of organic acids, *e.g.* gluconic acid and inorganic ions, *e.g.* phosphate, sulfate, *etc.* (Echingo and Takenaka, 1974). Other factors affecting honey acidity *e.g.* harvest seasons and floral types (El-Sherbiny and Rizk, 1979 and Pérez-Arquillué et al., 1994). In another study, Iftikhar et al. (2011) reported the following values: pH (3.84 and 5.60); acidity (29.37 and 27.87 meq/kg); moisture (17.68% and 22.06%) and HMF (27.37 and 23.18 mg/kg) in *A. mellifera* and *A. dorsata* honeys, respectively.

Nitrogen (N) content ranged from 3.28 mg/g (SMS honey) to 5.61 mg/g (PAG honey) with significant difference between the two values. The N content was also high in ALS, ARS1, CTE and CVE honeys without significant differences between values, while the remaining was in between. Total free amino acid and proline values showed the same trend as in the case of nitrogen (Table 3). Honey of a high protein content is considered to have more than 1 mg/g, while higher values (more than 2 mg/g) are due to high pollen content of floral origin (Azeredo et al., 2003). Major pollen components are proteins, amino acids, lipids and sugars (Atrouse et al., 2004).

Generally, tested honeys showed low proline contents. Honey of PAG had the highest value (1.88 mg/g), while the lowest one (1.14 mg/g) was for MKN2 with significant difference between the two values. Honeys of CVE, ALS and CTE showed also high proline content without significant differences between values. However Seder honeys had moderate values, Acacia types had low ones. The most abundant carboxylic acid in honey is proline (White et al., 1962). Proline is secreted mainly in bee saliva during the conversion of nectar into honey (Bergner and Hahn, 1972). Proline content is a criterion of honey ripeness and sometimes sugar adulteration (Bogdanov et al., 1999). It ranges between 202 and 680 mg/kg with 180 mg/kg as minimum accepted value for genuine honey, while higher values are related to honeydew honeys. White and Rudyj (1978) mentioned an average of 503 ppm for American honeys, also Thrasyvoulou and Manikis (1995) reported that this average was 526 ppm for Greek honey. Contrarily, wide proline range (343–1118 ppm) than indicated were reported for *A. mellifera* honeys (Joshi et al., 2000)

Antioxidants of honey include amino acids (proline, histidine, glycine and alanine). The correlation between radical scavenging activity (RSA) and proline content is higher than that between this activity and total phenolic content (Meda et al., 2005). High proline content was recorded by Joshi et al. (2000) being 875.8 and 610.2 mg/kg for *A. dorsata* and *A. mellifera* honeys, respectively.

Total phenols ranged between 0.44 mg/g (CTE) and 0.84 mg/g (ACS3) with significant difference between the two values. The other honey types showed in between values. Dark honeys, *e.g.* Acacia, Manuka and Tualang seemed to have more phenolic compounds than light ones (Table 3). Many phenolic compounds are found in honey with different quality and quantity according to the floral source. Honey phenolic

Table 4 Pigments contents (μg/g honey) in 23 honey samples produced in Saudi Arabia and 6 other countries.

Code	*T. chlorophylls*	*T. Carotenoids*		Xanthophylls	Anthocyanins
		By acetone	By ethanol		
ACS1	26.98c	71.16b	62.18bc	17.41de	15.60e
ACS2	30.70b	75.24b	66.70ab	17.04e	15.30e
ACS3	34.63a	88.93a	69.81a	26.90a	25.72a
SMS	31.98b	72.14b	64.72b	18.56d	18.72d
SDS1	19.76d	56.64bc	59.84bc	18.48d	14.63ef
SDS2	14.59f	48.90de	58.93c	16.98e	14.62ef
SDS3	19.94d	58.21bc	58.15c	13.92fg	10.96h
SHS	12.36g	45.04e	46.92de	18.29de	13.50fg
ALS	12.05g	41.29e	44.86e	10.04ij	08.13i
MFS1	20.79d	64.84b	46.60e	15.51f	13.81fg
MFS2	16.78e	50.24d	51.80cd	12.81g	10.73h
ARS1	12.10g	41.98e	44.70e	10.09ij	08.19i
ARS2	11.98g	41.86e	46.51e	10.85ij	08.75i
SDY	16.69e	51.14d	52.74cd	12.40gh	10.62h
CTE	12.12g	41.39e	44.69e	10.02ij	08.11i
CVE	11.99g	42.08e	44.80e	09.93ij	08.00i
CNE	12.07g	42.00e	46.92de	11.04hi	08.92i
MKN1	21.87d	68.15b	59.93bc	16.24ef	14.54ef
MKN2	30.56b	80.84b	68.81ab	24.79b	22.93b
BFG	19.98d	61.13b	58.04c	15.02f	13.24g
PAG	12.51g	45.00e	43.84e	09.34j	08.01i
JRA	18.84d	49.98de	54.39c	13.16g	11.42h
TUM	33.82a	77.61b	68.11ab	21.81c	19.98c

Values with varied letters differed significantly at 5%.

*ACS1,2,3 (*Acacia gerardii* honey from 3 locations, KSA), BFG (Black forest honey, Germany), SMS (*Acacia tortilis* honey, KSA), MKN 1&2 (Manuka honey 18% and 10% UFM, New Zealand), MFS 1&2 (Multifloral honeys 1&2, KSA) SHS (Shafallah- caper bush- honey, *Capparis spinosa*, KSA), SDS1,2,3 (Seder, *Ziziphus sp.* honey from 3 locations, KSA), SDY (Seder, *Z. sp.* honey, Yemen), TUM (Tualang tree Koompassia excelsa honey, Malaysia), CNE (Cotton honey, Egypt), JRA (Jarrah, Eucalyptus marginata honey, Australia), CVE (Clover honey, Egypt), PAG (Pseudoacacia trees, Robinia pseudoacacia honey, Germany), ARS 1&2 (Artificially fed colonies honey 1&2, KSA), CTE (Citrus honey, Egypt), and ALS (Alfalfa honey, KSA).

compounds are divided into three groups: flavonoids, cinnamic and benzoic acids (Amiot et al., 1989). Total phenolic content is a good criterion to determine the quality and curative properties of honey (Al-Mamary et al., 2002). Some authors reported that total phenols range between 20–2400 μg/100 g honey, *e.g.* in Malaysian Gelam and Coconut honeys were 21.4 μg/g and 15.6 μg/g, respectively (Aljadi and Kamaruddin, 2004); 2.13–12.11 mg/100 g in 5 Australian honeys (Yaoa et al., 2005); 64 and 1304 mg/100 g in 11 Algerian honeys (Ouchemoukh et al., 2007). Dark honeys have higher phenolic content than light ones; honeydew honeys have the highest amount. There was a strong correlation between antioxidant activity and phenolic content (Meda et al., 2005).

Total chlorophylls ranged between 11.99 μg/g (CVE) and 34.63 μg/g (ACS3) with significant difference between the two values, while almost other types had lower ones (Table 4). However, carotenoids were the largest occuring pigments found in all tested honeys, while xanthophylls and anthocyanins were the lowest ones. Also, dark honeys were rich in their pigment content than light ones. Honey contains antioxidants *e.g.* beta-carotene, catalase, and peroxidase (Crane, 1990; D'Arcy, 2005 and Bertoncelj et al., 2007). It is known that chemical oxidants in foods produce toxic oxygen which impairs the DNA and may lead to microbial infection or cancer (Weirich et al., 2002).

Minor components in honey include plant pigments, *e.g.* carotenes, chlorophylls and xanthophylls (White, 1975). Carotenoids were largely responsible for the color of light honey, but a coloring matter of dark honey appeared to be water-soluble and this could be due to the ash and amino acid/sugar explanations of honey colors (Molan, 1998). Another study described the coloring matter of honey as carotenoids and anthocyanins (Thawley, 1969). Analysis of organic substances in honey could assist in the identification of its floral origin. Carotenoids occur in some honeys between 100 and 180 μg/g, and dark-colored honeys seem to contain more antioxidants than do lighter ones (Tan et al., 1988). Egyptian cotton honey had high pigment content compared to citrus or clover ones (Owayss et al., 2004). They mentioned that the importance of pigments is not only contributing as "markers" of the origin of bee products or to detect adulteration, but also many of them (especially carotenoids) are more valuable substances as vitamins and antioxidants. Dietary antioxidants, *e.g.* carotenoids have particular defense against degenerative diseases (Stampfer and Rimm, 1995). Flavonoids and phenolic acids are considerably more potent antioxidants than vitamins C and E (Vinson et al., 1995).

4. Conclusion

Tested Saudi Acacia and Seder honeys showed high values of density and of total soluble solids, but had low values of water content compared to exotic ones. Some Acacia and Manuka samples had higher HMF contents than those of maximum permitted levels. All the tested honeys were acidic; however Acacia honey had total acidity values over those of permitted levels, while most remaining types were comparable or acceptable. Also, Saudi Acacia and Egyptian honeys contained more total nitrogen, free amino acids and proline than those of other tested types. Dark-colored honeys, *e.g.* Acacia contained more phenolic compounds than those of light-colored ones. Carotenoids were the most predominant floral pigments in all the tested honeys, while xanthophylls and anthocyanins were the least ones. Seder honeys showed moderate values of the tested characteristics compared to the other types. Accordingly, further research on specific physicochemical properties of Saudi Acacia honey especially acidity is very much recommended. New criteria based on regional characteristics of Saudi honeys including antioxidants, micro-constituents are suggested.

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