PHYSICAL-CHEMICAL CHARACTERIZATION, PHENOLIC CONTENT AND CONSUMER PREFERENCES OF *Apis mellifera* HONEY IN SOUTHERN JALISCO, MÉXICO

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SUMMARY

Honey is a sweet natural substance produced by bees (Apis mellifera *L) from flower nectars and is considered an important part of traditional medicine. This study was carried in Southern Jalisco, México, to characterize honey and identify consumer preferences. The variables evaluated were pH, total soluble solids, water activity, color, and total phenolic content; antioxidant capacity was determined with the DPPH and ABTS methods. Also, 384 questionnaires were applied to determine consumer preferences. The results were analyzed with an ANOVA. The pH of the honey samples ranged between 3.68 and 3.91. Soluble solids were 78.5-81.37ºBrix, and water activity was 0.573-0.638. Pfund degrees were between 34 and 125mm; 10 samples were amber-colored (73-113), four were dark amber (103-125), three were light amber (62-82), and one was white (34mm). Antioxidant capacity showed values of 35.364 -16.371 and, 52.787 - 12.189µM Trolox equivalent (TE)/100g honey, respectively. Total phenolic content varied between 62.131 and 136.841mg GA/100g. Of the studied population, 88% consumes honey; of these, 48% consume it because of its health benefits and 23% use it as a sweetener. Consumers prefer amber-toned honey of natural flavor and liquid consistency in presentations of 500 and 1000ml. Fifty-one percent of the consumers acquire honey directly from producers and 26% in commercial establishments. They are willing to pay US$ 3.33-4.44 per liter. Because of its quality, the honey studied from the municipalities of Southern Jalisco is suitable for commercialization in international markets, and could generate economic resources for the region.*

Introduction

Apiculture in México has been used as an instrument for development of marginal rural communities because it generates a large number of jobs (Magaña *et al*., 2012). México is among the first producers and exporters of honey in the world; in 2015 it was in sixth place, producing 61,881t and third as an exporter, exporting 45,000t with a value of US$ 150×10^6 (SAGARPA, 2016). The state of Jalisco is the third producer of honey in México, contributing 10%. In this state, apiculture directly benefits 40,000 producers and indirectly 400,000 more people; over 42,000 families depend on this activity. It has become a generator of foreign currency in the hands of 800 to 1,000 beekeepers, 50% of whom are concentrated in the Southern and Southeastern part of the state. Of Jalisco's honey producers, 58.5% have commercial and/or semi-commercial production. They are not limited to bulk production of this foodstuff but have a diversified and industrialized production (Contreras-Escareño *et al*., 2013).

Honey is a sweet natural substance produced by bees (*Apis mellifera* L) from flower nectars, which are secretions or excretions that the bees suck out and transform using a combination of specific substances (Martin *et al*., 2014). The composition of honey is so varied that there are no

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CARACTERIZACIÓN FÍSICOQUÍMICA, CONTENIDO FENÓLICO Y PREFERENCIAS DE LOS CONSUMIDORES DE MIEL DE *Apis mellífera* HONEY EN EL SUR DE JALISCO, MÉXICO

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RESUMEN

*La miel es una sustancia natural producida por las abejas (*Apis mellifera *L) de néctares de flores, siendo considerada parte importante de la medicina tradicional. A fin de caracterizar la miel y conocer las preferencias de los consumidores del Sur de Jalisco, México, se evaluaron pH, sólidos solubles totales, actividad de agua, color, contenido de fenoles totales, y capacidad antioxidante por los métodos DPPH y ABTS, y se aplicaron 384 encuestas. Los resultados se analizaron con un ANOVA. El pH de las muestras osciló entre 3,68-3,91, el contenido de sólidos solubles entre 78,5-81,37ºBrix y la actividad de agua fue de 0,573-0,638. Los grados Pfund estuvieron entre 34 y 125mm, resultando 10 muestras color ámbar (73-113), cuatro ámbar oscuro (103-125), tres ámbar claro (62-82) y una de color blanco (34mm). La capacidad antioxidante mostró valores de 26,11-80,98 y 28,96-106,98µM de ET/100g de miel, respectivamente, para DPPH y ABTS. El contenido de polifenoles totales varió 124,26-273,68mg GA/100g. En el Sur de Jalisco 88% de la población consume miel, de estos, el 48% la consume por los beneficios para la salud y el 23% como endulzante. Los consumidores prefieren la miel de tonos ámbar, sabor natural, consistencia liquida, en presentaciones de 500 y 1000ml; 51% de los consumidores la adquiere directamente del productor y 26% en comercios locales. Están dispuestos a pagar US$ 3,33-4,44 por litro. Por su calidad, la miel de los municipios del Sur de Jalisco es apta para la comercialización internacional y puede generar recursos económicos para la región.*

CARACTERIZAÇÃO FISICO-QUÍMICA, CONTEÚDO FENÓLICO E PREFERÊNCIAS DOS CONSUMIDORES DE MEL DE *Apis mellífera* NO SUL DE JALISCO, MÉXICO

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RESUMO

*O mel é uma substância natural produzida pelas abelhas (*Apis mellifera *L) de néctares de flores, sendo considerada parte importante da medicina tradicional. Com o fim de caracterizar o mel e conhecer as preferências dos consumidores do Sul de Jalisco, México, se avaliaram pH, sólidos solúveis totais, atividade de água, cor, conteúdo de fenóis totais, e capacidade antioxidante pelos métodos DPPH e ABTS, e se aplicaram 384 pesquisas. Os resultados se analisaram com um ANOVA. O pH das amostras oscilou entre 3,68-3,91, o conteúdo de sólidos solúveis entre 78,5-81,37ºBrix e a atividade de água foi de 0,573-0,638. Os graus Pfund estiveram entre 34 e 125mm, resultando 10 amostras na cor âmbar (73-113), quatro na cor âmbar escuro (103-125), três na cor âmbar claro (62-82) e uma na cor branca (34mm). A capacidade antioxidante mostrou valores de 26,11-80,98 e 28,96-106,98µM de ET/100g de mel, respectivamente, para DPPH e ABTS. O conteúdo de polifenóis totais variou 124,26-273,68mg GA/100g. No Sul de Jalisco 88% da população consome mel, de estes, 48% a consome pelos benefícios para a saúde e 23% como adoçante. Os consumidores preferem o mel de tons âmbar, sabor natural, consistência líquida, em apresentações de 500 e 1000ml; 51 % dos consumidores a obtêm diretamente do produtor e 26% em comércios locais. Estão dispostos a pagar entre US$ 3,33 e US$ 4,44 por litro. Por sua qualidade, o mel dos municípios do Sul de Jalisco é apta para a comercialização internacional e pode gerar recursos econômicos para a região.*

two honeys alike. Large differences exist in terms of color tone and phytochemical compounds (Rababah *et al*., 2014). This depends largely on the environment where it is produced, storage conditions, and specifically, the nectar collected by the bees (Wilczyńska, 2010; Ciappini *et al*., 2013; Ciappini and Stoppani, 2014).

Sugars and water are the main components of honey (>95%; Muñoz and Copaja, 2007). The other compounds, such as proteins, aromatic aldehydes, aromatic carboxylic acids, esters, carotenoids, terpenoids, flavonoids, as well as others, contribute to honey's flavor (Muñoz *et al*., 2007), while the quantity of acids and amino acids contribute to its aroma (Prost, 2007). Its color varies from extra-light, passing through amber tones and almost reaching black, sometimes with a typical yellow luminosity, or greenish or reddish tones. Color is related to contents of minerals, pollen and phenolic compounds (Ulloa *et al*., 2010). Dark honey has a high content of phenolic compounds and, consequently, a high antioxidant capacity (Ulloa *et al*., 2010). Polyphenols, together with other antioxidants, such as vitamins C and E and some enzymes (Wilczyńska, 2010; Maurya *et al*., 2014), play an important role in food preservation and human health, preventing damage caused by oxidizing agents (Rababah *et al*., 2014).

Defining physical-chemical attributes of honeys is important since international prices are largely determined by their color, flavor and moisture (Ciappini *et al*., 2013). The objective of this study was to characterize *Apis mellifera* honey produced and consumed in southern Jalisco and to determine the preferences of the consumers.

Materials and Methods

The study was conducted in the municipalities of Sayula, Ciudad Guzmán and Gómez Farías, which are part of the metropolitan zone of Southern Jalisco, México, located at 19°57'30"N and 103°46'05"W. The climate is warm sub-humid. The region has valleys and mountains and the economic activity is predominantly agriculture and animal husbandry. Vegetation is diverse and includes pine (*Pinus* spp.)

and Oak (*Quercus* spp.) mountain mesophyll forests. Eighteen samples of 100ml of honey producved by *Apis mellifera*, with three replicates, were collected from different beekeeperts and kept at 4°C for three months. Six samples were from Sayula, eight from Ciudad Guzmán and four from Gómez Farías.

Physical-chemical characteristics

The physical-chemical variables evaluated were color (Pfund degrees), pH, total soluble solids (TSS; ºBrix), water activity (Aw), total phenolic content (mg; gallic acid equivalents (GAE)/100g honey). Antioxidant capacity was determined by the DPPH and ABTS methods and expressed in µM Trolox equivalents (TE)/100g honey, and as percentage of inhibition. To measure Pfund mm, a spectrophotometer (Varian Cary 50 UV-vis, Agilent Technologies, China) was used. Three grams of honey were weighed and gauged to 10ml with distilled water. The mixture was homogenized by constant shaking and was then left to stand for 5min. Readings were done at 635nm using distilled water as a blank. Degrees Pfund were calculated with the formula Pfund (mm)= -37.70+371.39* absorbance. Color was determined with the honey color scale proposed by Montenegro *et al.* (2005), which indicates seven color standards with their equivalences in mm Pfund: 1) water white (0-8), 2) extra white (8-16.5), 3) white (16.5 -34), 4) extra light amber (34-50), 5) light amber (50-85), 6) amber (85-114) and 7) dark amber (>114). To measure pH, a PSC tester 35 (multi-parameter waterproof) was used at room temperature. ºBrix were measured with a refractometer ST-1 using an aliquot of 1ml. For the analysis of water activity (Aw), Aqualab Series 4la equipment was used and equilibrated with a solution of 0.1M HCl with an Aw of 0.984, that was used as the standard against which the samples were measured.

Determination of total phenolic content

Total phenolic content in the samples was determined with the Folin-Ciocalteu method (Waterman and Mole, 1994). The sample was prepared by diluting 5g of honey in 50ml distilled water. In an Eppendorf tube, 10µl of sample, 790µl water, 150µl Folin reagent (Sigma-Aldrich, Missoury, USA) and 150µl of 20% sodium bicarbonate were mixed and left to incubate for 1h protected from light, at room temperature. Absorbance was measured at 760nm using a UV-VIS Multiskan GO spectrophotometer (Thermo Fisher Scientific Corporation, MA, USA). A standard curve was constructed with 0.5 to 10µg·µl^{-1} gallic acid (GA; Sigma-Aldrich, Missoury, USA) and the results were expressed as mg GA/100g honey.

Antioxidant capacity by DPPH

Antioxidant capacity was determined in 5g honey diluted in25 ml distilled water with the DPPH method, following Bondet *et al.* (1997). A 150µM DPPH (2,2'-diphenyl-1-picryl hydrazyl; Sigma-Aldrich, Missoury, USA) solution was prepared. As a positive control, BHT (2,6-bis(1,1-dimethylethyl)-4-methylphenol) at a concentration of 0.1g·ml was used. For readings, 20µl of each sample, plus 200µl of the DPPH mixture were placed in a spectrophotometer (UV-VIS Multiskan GO) and absorbance read at 520nm. The standard curve was constructed with Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid; Sigma-Aldrich, Missoury, USA) from 0.1 to 5µM·ml^{-1}. Results were expressed in µmol of Trolox equivalents (TE)/100g honey.

Antioxidant capacity measured by ABTS

The capacity of the samples to capture free radicals with 2,2'azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS, Sigma-Aldrich, Missoury, USA) was determined in accordance with the procedure of Bekir *et al.* (2012) with a few modifications. The ABTS was produced with a 7mM ABTS stock solution with 2.5mM potassium persulfate, and remained for 16h in darkness at room temperature and 25rpm. The mixture was diluted with 100% methanol to obtain an absorbance of 0.70 ±0.02 at 734nm. For the readings, 20µl of each of the samples, plus 200µl ABTS dilution were placed in a spectrophotometer (UV-VIS Multiskan GO) and read at 734nm. The standard curve was constructed with 0.1-5µM·ml^{-1} Trolox. Results were expressed in µmol TE/100 g honey.

Statistical analysis

A two-way ANOVA was performed and means were compared with the Tukey test ($p \leq 0.05$), using SAS software (SAS, 2007).

Consumer preference study

An instrument validated by Swisscontact (2010) was used. The survey was conducted to identify preferences of consumers of three municipalities of southern Jalisco, in terms of color, consistency, flavor, presentation, container, periodicity and buying point, among others. Questionnaires (384) were applied in the three municipalities, distributed according to a stratified sampling method by number of inhabitants: 261 in Ciudad Guzmán, 88 in Sayula and 35 in Gómez Farías. Selection of participants was completely random, and the unique criterion for inclusion was a minimum age of 15 years. Sample size was calculated following Hernández *et al.* (2010) taking into account the total population older than 15 at the three study sites (INEGI, 2015). Confidence level was 95% and the maximum permissible error was 5%.

Results

Physical-chemical characteristics

Significant differences ($p \leq 0.05$) were found in TSS (°Brix), Aw, pH, antioxidant capacity by the DPPH and ABTS methods, total phenolic content and inhibition percentage by DPPH and ABTS. The pH of the samples analyzed fluctuated between 3.68 and 3.91. Soluble solids were in the range of 78.5 to 81.37 ºBrix, and water activity had values between 0.573 and 0.638. The botanical origin of most of the honeys was multiflora (Table I).

TABLE I
GEOGRAPHICAL ORIGIN, TYPES OF HONEY, TOTAL SOLUBLE SOLIDS, WATER ACTIVITY AND pH OF 18 HONEY SAMPLES OF SOUTHERN JALISCO, MÉXICO

#	Geographical origin	Type of honey	TSS (ºBrix)	Aw	pH
1	Sayula	Multiflora	81.1 abc	0.583 jk	3.68 c
2	Ciudad Guzmán	Multiflora	80.6 bcde	0.586 hij	3.85 bc
3	Ciudad Guzmán	Multiflora	80.5 cdef	0.573 kl	3.84 bc
4	Ciudad Guzmán	Multiflora	80.1 efg	0.590 efgh	3.86 bc
5	Gómez Farías	Multiflora	81.1 abc	0.576 kl	3.75 c
6	Ciudad Guzmán	Multiflora	81.2 ab	0.582 jkl	3.96 abc
7	Sayula	Multiflora	80.0 fg	0.605c	3.87 bc
8	Ciudad Guzmán	Multiflora	80.6 bcde	0.590 efgh	3.86 bc
9	Ciudad Guzmán	Multiflora	80.2 def	0.613b	3.90 abc
10	Sayula	Monoflora	80 fg	0.638a	3.68 c
11	Gómez Farías	Multiflora	80.5 cdef	0.587hij	3.80 bc
12	Sayula	Multiflora	81.3 a	0.587hij	3.91 abc
13	Gómez Farías	Multiflora	78.5 h	0.623 a	3.86 bc
14	Ciudad Guzmán	Multiflora	80.8 abcd	0.575 kl	3.91abc
15	Ciudad Guzmán	Multiflora	80.2 def	0.594def	3.86 bc
16	Gómez Farías	Multiflora	80.7 abcde	0.588 fghi	3.90 abc
17	Sayula	Multiflora	79.5 g	0.600 cd	3.81 bc
18	Sayula	Multiflora	79.8 fg	0.596 cde	3.73 c

Means with the same letter in a column are not significantly different (Tukey, $p \leq 0.05$).

TABLE II
PFUND DEGREE, COLOR AND ANTIOXIDANT CAPACITY, TOTAL PHENOLIC CONTENT, INHIBITION (PI) OF DPPH AND ABTS OF 18 HONEY SAMPLES OF SOUTHERN JALISCO, MEXICO

#	Pfund (mm)	Color	DPPH (μM de TE/100g)	ABTS (μM de TE/100g)	Total phenolic content (mg GA/100g)	PI of DPPH (%)	PI of ABTS (%)
1	94	A	29.47 a	42.38 cd	78.37 hi	24.3 ab	37.4 cd
2	100	A	34.17 a	42.38 cd	77.37 hij	28.5 a	37.4 cd
3	97	A	32.87 a	48.44 b	92.08 efg	27.1 a	42.9 b
4	92	A	35.36 a	37.21 ef	62.13 k	29.2 a	32.7 ef
5	120	DA	27.25 ab	26.95 g	110.15 c	19.7 ab	23.4 g
6	82	LA	31.75 a	44.01 c	94.21 def	26.3	38.9 c
7	118	DA	34.47 a	52.79 a	78.14 hi	27.9 a	46.9 a
8	113	A	29.29 a	34.11 f	102.93 cd	23.7 ab	29.9 f
9	86	A	27.92 ab	39.05 de	84.06 ghi	22.2 ab	34.4 de
10	34	W	16.37 b	12.19 h	119.74 b	12.7 b	9.9 h
11	101	A	27.10 ab	29.82 g	81.70 hi	23.3 ab	26.0 g
12	97	A	33.11 a	37.42 ef	136.84 a	26.8 a	32.9 ef
13	73	LA	30.71 a	48.25 b	68.55 jk	23.2 ab	42.8 b
14	113	DA	26.93 ab	27.35 g	81.60 hi	21.2 ab	23.7 g
15	90	A	29.63 a	35.53 ef	76.11 ij	23.2 ab	31.2 ef
16	62	LA	28.29 ab	36.15 ef	86.23 fgh	23.8 ab	31.7 ef
17	95	A	32.18 a	26.71 g	97.71 de	25.8 a	23.2 g
18	125	DA	26.92 ab	46.45 bc	81.70 hi	21.1 ab	41.1 cb

A: amber, DA: dark amber, LA: light amber, W: white. Means with the same letter in a column are not significantly different (Tukey, p≤0.05).

The range of colors of the samples analyzed only partially represented the Pfund scale; only four of the seven colors proposed by Montenegro *et al.* (2005) were found. Values (Table II) were 62-125mm Pfund, resulting in 10 amber-colored (73-113mm Pfund) samples, four dark amber (103-125mm Pfund), three light amber (62-82mm Pfund) and one white (34mm Pfund).

Antioxidant capacity determined with the DPPH method showed values of 16.37-35.36μM of TE/100g honey. The statistical differences found among honeys reflect the fact that the variants of amber (light to dark) are statistically similar and only the white honey separates clearly from the former group (Sample 10, Table II). Antioxidant capacity of the dark honeys is between 26.92 and 34.47, that of amber is 27.10 to 35.36, that of light amber is 28.29 to 31.75, while that of white honey is 16.37μM TE/100g honey (Table II).

The ABTS method showed antioxidant capacity of 12.19-52.79μM TE/100g honey. For dark amber honey, the values were 26.95-52.79, for amber honey 26.71-48.44, for light amber 36.15-48.25 and for white honey 12.19μM TE/100g. It can be seen that antioxidant capacity is higher in darker honeys. Comparing the antioxidant capacity data obtained with DPPH and with ABTS, it can be observed that ABTS data were slightly higher (Table II).

Total phenolic content oscillated between 62.13-136.84mg GA/100g in amber colored honeys. In the case of dark amber honey, the values were 78.14-110.15; for light amber, the values were 68.55-94.21, while for white honey it was 119.74mg GA/100g. It can be seen that the amber colored honeys have values at the extreme ends of the range, which includes practically all the honey colors. Although there were statistical differences, total phenolic content did not differentiate colors (Table II).

The percentage of inhibition with the DPPH method was between 12.7 and 29.2: 21.1-27.9% in dark amber honey, 22.2-29.2% in amber honey, 23.2- 26.3% in light amber honey and 12.7% in white honey. With the ABTS method, the values were in the range of 9.9-46.9%. White honey had the lowest inhibition values with 9.9%, contrasting with dark honeys, which had the highest percentages (23.4-46.9%), followed by amber and light amber honeys (23.2-42.9 and 31.7-42.8%, respectively) (Table II).

The sample identified with number 10 (from Sayula), which is white, has the lowest values for antioxidant capacity determined by the DPPH and ABTS methods with values of 16.37 and 12.19μM TE/100g, respectively. In contrast, in total phenolic content, it is among the highest values (119.74mg GA/100g honey). Although it is inferior to the amber-colored sample 12, it was statistically superior to the rest (Table II).

Consumer preferences

Based on the survey, 88% of the total population consumes honey. In the municipalities of Ciudad Guzman, Sayula and Gómez Farías, only 13, 5 and 20%, respectively, do not consume honey. The population has varied uses for honey. Medicinal use (48%) is outstanding, followed by its use as a sweetener (23%), to accompany food (16%) and for cooking (13%). Specifically, in the municipalities of Ciudad Guzman and Sayula, the main use is medicinal with 56 and 41%, respectively, followed by its consumption as a sweetener by 20-46% of the population.

In terms of color preferences, 70% of the population prefer light amber, amber and dark amber honey, while only 30% prefer white honey. In the municipalities of Sayula and Gómez Farías, 67 and 69% of the consumers tend to prefer amber to dark amber honeys, respectively. In contrast, 29% of the consumers of Ciudad Guzmán prefer light amber honey and 38% prefer white honey; that is, 67% of the population prefer light-colored honeys. Regarding flavor, 98.8% of the total population expressed preference for natural flavor against acid or eucalyptus flavored honey. Eighty percent of the total population prefer liquid honey, while 20% prefer viscous honey. In Ciudad Guzman, Sayula and Gomez Farias, 87, 63 and 74%, respectively, prefer liquid honey. In terms of which attribute is the most important in guiding their choice of honey, 37% base their decision on flavor, 32% on color, and 31% on consistency. In the case of Gómez Farias, the result is clear: 74% of the population base their decision to buy on color, while in Ciudad Guzman and Gómez Farias, flavor is the decisive aspect in acquiring honey (Table III).

Regarding the container, 51% of the total population prefer glass containers, while 49% prefer plastic. However, in Sayula and Gómez Farias 58% and 67%, respectively, would choose plastic over glass. In contrast, in Ciudad Guzmán, most (53%) prefer glass containers. Most of the population prefer containers with no particular design and local honey, 85 and 95%, respectively, while 52% like presentations of 500ml and 32% prefer 1000ml containers. The frequency with which consumers buy honey is a monthly one for 37% of the total population and every two weeks for 29%. It is important to mention that the population of the municipalities studied consume

TABLE III
USE AND CONSUMPTION PREFERENCES OF HONEY IN THE MUNICIPALITIES OF CIUDAD GUZMÁN, SAYULA AND GÓMEZ FARÍAS JALISCO, MEXICO

Question	Answer	Total population[1]	Cd. Guzmán[2]	Sayula[3]	Gómez Farías[4]
Do you eat honey?	Yes	63	60	74	60
	No	12	13	5	20
	Sometimes	25	27	21	20
What is the use of honey?	Sweetener	23	21	20	46
	Cooking	13	10	18	27
	Medicinal	48	56	41	7
	Food	16	13	21	20
What is the color that you prefer?	Dark amber	21	23	15	22
	Amber	23	10	52	47
	Light amber	26	29	21	21
	White	30	38	12	10
What is the flavor that you prefer?	Natural	98.8	100	100	86
	Acid	0.6	0	0	7
	Eucalyptus	0.6	0	0	7
What is the consistency that you prefer?	Liquid	80	87	63	74
	Viscous	20	13	37	26
Which attribute is most important for the choice of honey?	Color	32	32	17	74
	Consistency	31	30	41	13
	Flavor	37	38	42	13

1, 2, 3 and 4: percentage (%) calculated from 384, 261, 88 and 35questionnaires, respectively.

very little honey from supermarkets (23%), 26% buy honey at local stores, and 51% buy directly from producers, the majority of whom do not have a brand name or a specific container design. In the municipalities of Ciudad Guzmán and Sayula, honey is bought mostly from the producer and, in Gómez Farias, at local stores. Most of the population is happy to pay MX$ 60-80 (US$ 3.33-4.44) per liter. However, 25% of honey consumers of Sayula are willing to pay a higher price, MX$ 91-100 pesos (US$ 5.05-5.55). If the price goes up, 93, 79 and 73% of the populations of Ciudad Guzman, Sayula and Gómez Farías, respectively, would be willing to pay more (Table IV).

TABLE IV
PREFERENCES OF HONEY CONSUMERS IN THE THREE LOCATIONS

Item	Preferences	Total population[1]	Municipalities		
			Ciudad Guzmán[2]	Sayula[3]	Gómez Farías[4]
Container	Plastic	49	53	42	33
	Glass	51	47	58	67
Brand name or special container design	Yes	15	13	21	20
	No	85	87	79	80
Origin	Introduced	5	0	16	13
	Local regional	95	100	84	87
Presentation	1000ml	32	26	42	47
	750ml	8	7	11	13
	500ml	52	60	37	27
	250ml	8	7	10	13
Periodicity	Weekly	13	14	10	13
	Biweekly	29	33	16	34
	Monthly	37	33	47	40
	Bimonthly	11	13	11	0
	Biannually	10	7	16	13
Buying point	Supermarkets	23	26	21	7
	Local stores	26	27	11	60
	Producer	51	47	68	33
Price willing to pay	<60	5	0	21	5
	60-70	43	46	32	46
	71-80	39	47	16	33
	81-90	7	7	5	10
	91-100	6	0	26	6
Would be willing to pay more	Yes	88	93	79	73
	No	12	7	21	27

1,2,3 and 4: percentage (%) calculated from 384, 261, 88 and 35questionnaires, respectively.

Discussion

Physical-chemical characterization

The results obtained in this study on pH (3.68-3.91) coincide with those obtained by Cabrera and Batista (2010), who found values of 3.91 and 4.18. These authors mention that these values reflect good quality honey. Parada (2003) obtained similar results but in a broader range, reporting pH values of 3.2-4.5. However, honeys from southern Jalisco have pH at the lower limit of the values found by Ng´ang´a *et al.* (2013), indicating that the honeys of this region are more acid. This condition favors its conservation since a low pH inhibits the presence and growth of microorganisms and makes honey more compatible with many food products. Moreover, pH is not significantly affected by storage time, as long as the honey is kept at a temperature between 10 and 20ºC (Parada, 2003).

The range of total soluble solids values of our study, 78.5-81.37°Brix, was similar to those obtained by Lino (2002), 77.31-85.66°Brix. These data indicate that the honey produced in southern Jalisco is of good quality, although it is important to point out that the honeys with higher contents of TSS have the disadvantage of crystalizing more easily than honeys with lower concentrations. Some consumers do not like how it looks and believe erroneously that it indicates adulteration when it is actually a natural process in honey (Prost, 2007). Brix degrees represent the weight percentage of chemically pure sucrose in the distilled water solution at 293K or 20°C (NOM, 1984).

The water activity values of 0.573-0.638 are considered reliable values, indicating that growth of microorganisms is inhibited. According to Mossel *et al.* (2003), water activity of honey ranges between 0.490 and 0.650, which guarantees a safe food since microorganisms do not multiply when Aw is <0.60. According to Badui (2006), an Aw >0.7 allows growth of fungi, yeasts, bacteria. In our study, 14 of the honey samples analyzed have an Aw <0.60 and only four were between 0.605 and 0.638, suggesting that most of the honeys have a long shelf life, an important attribute in food quality. Moreover, the rate of darkening reaction of honey is practically zero when Aw is <0.4, but above >0.6, the reaction rate is more than 20. Thus, the values obtained indicate that the honeys do not favor growth of fungi, yeasts or bacteria.

The color data obtained, 34-125mm Pfund, coincide with data obtained in Chilean honey, of 50.0-128.7mm Pfund (Martin *et al.*, 2014) and Czech honey, of 22-132mm Pfund (Vit *et al.*, 2008). The color of the honey produced in southern Jalisco tends to be dark; 14 of the samples were between amber and dark amber. Generally, dark amber-colored honey is from mountains and forests (Herrero, 2004) and the study region areas are predominantly mountain forests. Color is an important trait in consumer preferences of honey quality and international markets demand specific honey colors. For example (Delmoro *et al.*, 2010), Northamericans prefer light-colored honey: water white, extra white and white tones (0-34mm Pfund), which also have a less intense flavor, while in Europe darker honey, with more potent flavors, are privileged: extra light amber, light amber and dark amber (34 to 114mm Pfund). Color varies depending on the flowers from which bees collect the nectar that will later become honey (Martin *et al.*, 2014; Herrero, 2004). It has been reported that dark amber honeys are rich in vitamins B and C, while light honeys are associated with more vitamin A (Herrero, 2004) and with flowers of a single species (Martin *et al.*, 2014). The color of each honey is due to small quantities of pigments such as carotenoids and flavonoids, which determine the difference between a light and a dark honey and contribute antioxidant capacity (Ciappini *et al.*, 2013).

Recently, there has been growing interest in determining the antioxidant capacity of honey. Many studies indicate that the antioxidant capacity varies widely depending on the flower source (Ulloa *et al.*, 2010; Maurya *et al.*, 2014). They propose that the antioxidant activity of honeys could be a positive influence factor in terms of honey differentiation (Mellen *et al.*, 2015). In our study, the variation was due to the multi-floral and multi-environment sources of most of the honeys studied, making it difficult to find honeys with the same characteristics, as Córdova-Córdova *et al.* (2013) and Rababah *et al.* (2014) report. The antioxidant capacity obtained in our study (26.952-52.787µM TE/100g honey) with the ABTS method was lower than the values obtained in Czech honeys (43.55-290.35µM TE/100g honey; Vit *et al.*, 2008). The difference may be due to different production conditions, environments and sources of nectars (Ciappini and Stoppani, 2014). In general, the darker honeys had higher values of antioxidant capacity with the ABTS method than white honey, coinciding with Wilczyńska (2010).

The percentages of inhibition found in the present study are lower than those reported by Neupane *et al.* (2015), who report percentages of inhibition determined by the DPPH method of 76.66% and 25.69% in honeys obtained at high and low altitudes, respectively.

Total phenolic content (62.131-136.841mg GA/100g) of the honeys from Southern Jalisco shows certain similarity to that of honeys from Argentina (40.3-193mg GA/100g), (Ciappini and Stoppani., 2014), from the Czech Republic (47.39-265.49), from Paraguay (125-176.5, average 148.29) and from Sudan (79.4-232.7mg GA/100g; Tahir *et al.*, 2015), but is lower than honey from Argentina (144.22-431.20, average 240.74; Vit *et al.*, 2008). In contrast, honeys from Southern Jalisco have a higher phenolic content than honeys from Jordan as reported by Rababah *et al.* (2014) with values of 33.7-86.3. In our study, the phenolic content did not differentiate honey colors; white honeys had values similar to those of dark honeys. This is contrary to Wilczyńska (2010), who reported that dark honey had a higher phenolic content than pale honey, which had the lowest values. In this respect, Córdova-Córdova *et al.*, (2013) mention that physical-chemical analyses for the case of honeys from Tabasco, México, cannot be used to differentiate honeys, and much less to characterize them, because they did not find significant differences.

Consumer preferences

A highly marked preference for amber to dark amber colored honey was observed in the three municipalities. This is contrary to consumer preferences in Honduras, where 75% prefer light-colored honey and 25% dark honey (Swisscontact, 2010). Students in Skierniewice, Poland, also preferred light honey: 98.1% selected light-colored honey over dark (Pidek, 2001). However, the preference found for the honey produced by beekeepers of in Southern Jalisco may be very positive for its commercialization in the region as well as in Europe (Delmoro *et al.*, 2010) since it is mostly amber-colored (14 of 18 samples). Generally, the amber-colored honeys are from mountainous or forested areas and are related to high contents of minerals and vitamins B and C, which is normally obtained from flowers of oak trees (*Quercus* spp.) (Herrero, 2004). Likewise, consumer preference based on medicinal use of honey is related to the amber and dark amber honey produced in the region. Different authors have demonstrated that dark honey has higher antioxidant capacity and polyphenol content (Ulloa *et al.*, 2010). In contrast, 29 and 38% of the population of Ciudad Guzmán prefer light amber and white honey, also associated with medicinal use. In this regard, Herrero (2004) associates light amber honeys with more vitamin A.

Preferences vary greatly with culture, economic conditions and location of the consumers. In Honduras, for example, according to Swisscontact (2010), 57 and 32% of the population buy honey in supermarkets and specialized stores, respectively. In contrast, in Southern Jalisco 51 and 26% of the population buy honey in producer and local stores, respectively, possibly because the region is an important producer. While in Honduras consumers prefer viscous honey and plastic containers, the consumers of our study prefer honeys of more liquid consistency and glass containers (51%). Hondurans prefer containers of 1000 (27%), 750 (25%), 500 (22%) and 250ml (11%). In contrast, the consumers of Southern Jalisco tend to prefer 500ml containers, and fewer prefer 1000ml containers. Despite this differences, there are also similarities to other consumer studies. Honey consumers of the Democratic Republic of the Congo choose local forest honey (Amos *et al.*, 2014), like the consumers of our study who prefer local regional honey. The consumers of Honduras coincide with those of our study in diverse aspects that condition their preferences, such as medicinal use of honey as determinant (34%), together with its use as a sweetener (43%). The consumers of Honduras also prefer honeys with natural flavor and they buy honey every 15 to 30 days, as do the populations of the locations studied herein. Another coincidence with other consumers, students of Skierniewice, is the preference for honey of more liquid consistence (Pidek 2001).

Based on our results, it can be argued that the honey studied from the three municipalities of Southern Jalisco is of a very good export quality and also has potential in the region because of the preferences of local consumers.

Conclusion

The antioxidant capacity and percentages of inhibition determined by the DPPH and ABTS methods revealed higher values in amber-colored honey than in white honey, while phenolic content does not differentiate the samples according to their color.

This is the first study on the physical-chemical characteristics and local consumer preferences of *Apis mellifera* honey in the southern region of Jalisco. The honey from Southern Jalisco varies widely, and has an excellent export quality and potential for regional commercialization, since the population prefers local honey over brand name honey sold in supermarkets. Eighty-eight percent of the population consumes honey. Medicinal use is outstanding (48%), followed by use as a sweetener (23%). Consumers prefer amber tones with natural flavor and liquid consistency in presentations of 500 and 1000ml. Fifty-one percent of the population buy honey directly from the producer and 26% in local stores. Most of the honey does not have a brand name or special container design. Most of the population is content to pay between MX$ 60 and 80 (US$ 3.33-4.44) per liter, but would be willing to continue buying if the price went up.

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