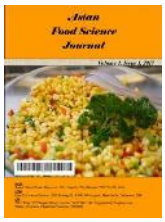

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Bee Honey Color Variation throughout the Year

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Bee honey is a highly valued food whose international marketing is controlled by quality standards that are based on its physicochemical properties. One of them is color, which does not reflect a high or low quality, but rather the preferences of certain consumer markets. Color in honey is mostly determined by its floral sources that constantly change throughout the year. This study was intended to record color variations of the honey collected by *Apis mellifera*. For this purpose, honey was sampled from three selected hives, in an apiary in the town of Huejotitan, state of Jalisco, in western Mexico, on a monthly basis for a year. Color was measured according to the Pfund scale. Humidity was also measured since fermentation due to excessive moisture could spoil the samples. Two additional samples were collected, as well, from the bulk of honey at the time of the harvests, directly from the extractor: one from the spring harvest in May 2012, and the other from the fall harvest in December 2012. A total of 23 samples were obtained from December 2011 to December 2012. Color ranged from 0 mm Pfund (water white) to 85 mm Pfund (light amber) and

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humidity from 17% to 24%. It was discovered that the samples collected during the peak of the nectar flow, October - November, were contrastingly whiter than the rest. Although requiring more work, since consumers prefer clearer honeys, it is concluded that honey harvested at intervals during the high flow in the hives, with careful consideration of the moisture and making sure to keep honeys from different hives, apiaries and producers separate, a wider variety of honeys would be obtained, with different shades of color and different properties, better targeting the more specialized and demanding markets of today.

Keywords: Floral sources; physicochemical properties; blooming season; capped honeycomb.

1. INTRODUCTION

Bee honey, the sweet natural substance produced by *Apis mellifera* from the nectar of flowers and other plant secretions, has been hunted and harvested since the earliest times of human history [1]; until the domestication and extensive cultivation of the sugar cane, it was the most widely used and appreciated sweetener in the world [2]. For bees, honey is mainly the carbohydrate constituent of their diet. For humans, it is a highly-valued food whose characteristics have been classified and regulated in order to meet the requirements of quality and the standards of preference in the eclectic international markets.

Color is one of the most important properties of honey and the one that normally comes first, partly because color is the first parameter perceived by the consumers [3]. Although color is in reality just a human perception, when it comes to honey it is of paramount importance not only because it is related to other physicochemical properties but also because it has different degrees of acceptance in different parts of the world and has become a key aspect in the determination of price [4]. For example, Americans prefer lighter honeys, between 0 and 34 mm Pfund, while Europeans prefer the darker ones, between 34 and 114 mm Pfund [2]. Thus, color is not directly related to quality in terms of low or high; instead, it is just a reflection of the cultural preferences of a region or nation.

However, color cannot be dealt with subjectively. In order to have a consensus and understanding, numerical values have been successfully assigned [5] through a variety of methodologies. Although honey colors were originally assigned by experts relying only on their sight, presently it is done by means of very modern but at the same time very simple technology. From several options, the European Union Directives [6], the Codex Alimentarius [7] and the International Honey Commission (IHC) have selected and established a series of standards to measure the quality of honey. In terms of color, honey is most commonly graded according to the Pfund and the Lovibond scales [8].

Although honey color is related to production processes, temperature and storage conditions [9], the most important determining factor is the floral source [10,11]. Throughout the year, floral resources are temporary and random. This means that the floral composition changes gradually in a given landscape, except in cases of extensive single crops, and the physicochemical properties, especially color, change accordingly. The bulk of honey stored in the combs reflects those characteristics of the blooms that are dominant at any given time. If at harvest, beekeepers, and, later, middle men and exporters, mix together honeys form different hives, from different apiaries and from different producers into single lots, what once were many different and very particular batches will be converted into a homogenous whole that loses the particularities of its original components. That is what normally happens. There are several practical reasons for it but the two most important ones are, first, that honey is harvested all at the same time, otherwise the extraction process would take too much time and the operative costs would rise. And, second, honey is harvested at the end of the blooming season when the bees have capped the honeycomb. This signals that the honey has lost excess humidity and it is said to be "ripe". If harvested before, there is a high risk of fermentation. The international standards suggest a maximum of 21% moisture content although some European countries allow no more than 18.5% in their honey imports [12]. Despite the impracticality of harvesting at intervals and the risk of fermentation, at least theoretically, if honey were collected at intervals from single hives, avoiding at all costs mixing with other honeys, the result would be different honeys with different colors. Since colors are related to the other physicochemical properties, we would assume

that those would vary as well. The purpose of this study was to determine color variation throughout the year in a single apiary.

2. MATERIALS AND METHODS

The current investigation involved sampling bee honey in one single apiary in the municipality of Jocotepec, state of Jalisco, in western México, to determine color variation. The site was selected within an area of importance for beekeeping.

Jocotepec is located on the west side of Chapala Lake and extends over an area of 384.36 km2, known as Región de las Cuencas Centrales [13]. 61% of its surface is covered by mountains reaching heights of 2,960 m.a.s.l [14]. The apiary was located outside the town of Huejotitan, 20°21'13.45''N, 103°29'6.97''O, behind the old hacienda, 11 km northwest of the lake and 2 km south of Cerro Viejo, the highest peak of the mountain range, which runs from west to east. The elevation at the site is 1,597 m.a.s.l. around the apiary. The land cover is dominated by seasonal cultivated crops, pastures and secondary vegetation interspersed with tropical deciduous forest. The overall land cover in the valley includes meadows, different associations of secondary vegetation where cultivated land has been let to rest, and aquatic vegetation in the streams and lake. In the mountains there is an important extension of tropical deciduous forest in the low parts of slopes, cloud forest in the ravines and oak forest in the summits and high parts of the slopes, all of which account for a very diverse flora. The most abundant crops are *Zea mayz*, *Sorghum bicolor*, *Phaseolus vulgaris*, *Cucurbita* spp., *Sacharum officinarum*, *Sechium edule*, *Lycopersicon esculentum*, *Allium cepa*, *Triticum aestivum* and *Cicer arietinum*. Increasingly, greenhouses are built for strawberry (*Fragaria ananassa*) and raspberry (*Rubus idaeus*) culture. Urbanization has picked up in recent years.

Out of 23 bee hives in the apiary, three were chosen (for their strength) to be sampled once a month for a year, from December 2011 to November 2012. Each hive was provided with empty framed combs in a medium super for honey storage. On each visit, the combs containing honey were scraped with a spoon and the honey was poured into 110 ml glass jars, filled up as much as possible, one for each hive. Preference was given to extracting the honey from capped honeycombs.

The samples were processed at the premises of the Laboratory of Biology, Universidad Autonoma Agraria Antonio Narro, in the city of Torreon, state of Coahuila, Mexico. Color was measured with a C221 Hanna® Honey Colour Analyzer (Hanna® Instruments Inc. USA). Grading was done following the Pfund scale (Table 1) [15]. Humidity was measured with a M00596 Standard EA refractometer to anticipate risks of fermentation.

Table 1. Pfund scale and the equivalence in honey color classification names [4]

mm Pfund	International scale
0 - 8	Water white
9 - 17	Extra white
18 - 34	White
35 - 50	Extra light amber
51 - 85	Light amber
86 - 114	Amber
> 114	Dark amber

3. RESULTS AND DISCUSSION

A total of 23 honey samples were obtained from 08 December 2011 to 12 December 2012. On 02 February 2012, hive one had no honey. On 31 May 2012, hives one and three had no honey. No honey was found in the combs from July to September.

The color of the samples varied from month to month with a tendency to change from the darker (Dec 2011) to the lighter (Nov 2012) shades (Fig. 1). Nevertheless, regardless of our visual perception, most samples were comprised within the light amber range, even the darkest one (85 mm Pfund), according to the measurements. The lowest value, corresponding to the water white shade of color, was 0 mm Pfund (Table 2).

It was discovered that the samples collected during the peak of the nectar flow, October - November, were contrastingly whiter than the rest, including the sample belonging to the fall harvest, which was "white" in shade. These samples correspond to the pre-harvest period, when the blooms and the honey flow in the apiary were at their peak.

This means that once the honeys stored at different moments during the season, in the different hives, are harvested together and extracted at the same time at the end of the blooming period, they all become homogenized

Table 2. Results of the color and humidity measurements for the honey samples taken in each hive

Sample date	Hive	mm Pfund	Color	Humidity %
08 DEC 2011	1	70	light amber	20
	2	85	light amber	20.5
	3	68	light amber	18.5
02 FEB 2012	1	x	x	x
	2	56	light amber	20
	3	59	light amber	21.5
09 MAR 2012	1	65	light amber	18
	2	57	light amber	17.5
	3	68	light amber	19.5
11 APR 2012	1	18	white	16
	2	54	light amber	18
	3	40	extra light amber	21
11 MAY 2012	1	21	white	17.5
	2	55	light amber	19
	3	27	white	19
Harvest 11 May 2012	from extractor	51	light amber	18
31 MAY 2012	1	x	x	x
	2	70	light amber	18.5
	3	x	x	x
07 OCT 2012	1	0	water white	22
	2	0	water white	21
	3	0	water white	24
09 NOV 2012	1	0	water white	17
	2	0	water white	19
	3	0	water white	16.5
Harvest 12 Dec 2012	from extractor	20	white	18

The "x" means no honey was found in that hive on that date. From July to September no honey was found in the hives.

Fig. 1. Color variation of the samples, from water white to light amber

in their color and properties, turning into one single whole. It is like taking a five course meal, putting it all in a blender and then eating it in one single serving. Instead of enjoying and benefiting from five different exquisite delights, we would only have one big mess. At the

gourmet, medicinal, and commercial levels, this is what normally happens with bee honey.

Equally varied was the humidity content, which ranged from 17% to 24%, both of which correspond to water white samples. Most samples were within the international humidity limits; only three of them slightly surpassed the range: 21.5, 22 and 24% (Table 2).

4. CONCLUSION

The variation in the shades of color from month to month was an indicator, and confirmation, of the change in floral resources as the year passed, especially during the blooming season. The lighter shades of honey are related to a lower mineral content, milder flavors and subtle aromas while the darker shades relate to the opposite, stronger flavors and aromas and a higher mineral content [16]. Since the American Continent markets tend to prefer lighter honeys, it could be assumed that they would be in higher demand.

Although more work would be invested, since consumers prefer clearer honeys, it is concluded that honey harvested at intervals during the high flow in the hives, with careful consideration of the moisture and making sure to keep honeys from different hives, apiaries and producers separate, a wider variety of honeys would be obtained, with different shades of color and different properties, better targeting the more specialized and demanding markets of today.

Finally, as of the date of submission of this short research note, after more than five years of storage in their jars, in the dark, the honey samples used for this study did not and have not fermented despite some of them having humidity levels slightly above the international standards.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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