CHANGES IN WATER CONTENT OF HONEY DURING RIPENING UNDER CONTROLLED CONDITION

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Summary

The aim of the study was to determine the conditions under which the water excess evaporates from unripe honey and to examine the dynamics of the process. Different unifloral honey samples collected in apiaries of the Apiculture Division and in commercial apiaries provided the experiment material. During three years of the experiment, 79 samples of unripe honeys, 79 samples of dehydrated honeys and 69 samples of in-hive-ripening honeys were collected. Dehydration of honey samples was performed using a Chigo® heat pump air dehumidifier. The efficiency of the dehumidifier was 0.8l/hr according to the manufacturer's specifications with an airflow rate of ca. $200m^3$/hr. The dehumidifier was placed in a special chamber of $1.07m^3$ capacity, made of wood and covered with polyethylene foil. The initial water content of the honeys was 22.9%. During a 36 hrs of dehydration process the average water content was lowered to 15.9%.

Keywords: honey, water content,dehydration process, air dehumidifier, out-of-hive ripening of honey.

INTRODUCTION

Water content in the honey is important first of all because it affects its storage potential. While nectar or honeydew is processed by bees into honey its water content drops from the initial 80–85% of the total weight of the product to 16-20%. A number of factors decide about the final value of that parameter in honey produced by honeybee colonies, there are a low air humidity, medium abundance of nectar flow, good colony strength and ventilation of the beehive.

Water content below 17% prevents the fermentation and guaranties good honey storage regardless of the count of osmophilic yeast present in the product (Lochhead 1933, Stephen 1946). The danger of honey fermentation is the greatest when moisture content exceeds 20% (Lochhead 1933, Sanz et al. 1995, Bath and Singh 1999). Acceptable water content of honey is specified by honey quality standards, both in the world standard (Codex Alimentarius Commission 2001) and in the EU Directive (Council Directive 2002). In an analogous manner to these requirements the Polish Norm (Miód Pszczeli PN – 88/A–77626) and the Ruling by the Minister of Agriculture and Rural Development of Oct. 3, 2003 are specified. According to these documents, the acceptable water content of all unifloral honeys, with the exception of heather honey, should not exceed 20%. In heather honey, water content should not be higher than 23%.

Measurement of water content is the basic test to determine physicochemical characteristics of honey. In routine tests conducted over the years 1989 – 1997 in 91 to 95% out of total 30,000 honey samples had water content below 20% (Lüllmann 1989–1997). From among over 5,000 honey samples originating from 21 European countries the largest group of honeys (53%) had water content between 16 and 18%. In another 27% of honey samples water content was below 16%, in 19% of samples water content was between 18.1 and 20% whereas honey samples with water content above 20% accounted for slightly more than 1% (Persano Oddo and Piro 2004). Out of all honey varieties, heather honey had the highest water content (15.6% – 24.6%) (Rybak 1986, Persano Oddo and Piro 2004).

Numerous investigations proved that the average water content of the most frequently harvested varieties of honey (oilseed rape, acacia, linden and honeydew honey) is very similar (from 16.5 to 19%) and in buckwheat honey from 18.8 to 22.14% (Rychlik and Fedorowska 1965, Rybak 1986). When extracted too early, the final product is high in moisture. From among 163.5 tons of honey supplied into purchasing centres in the Polish Warmia and Mazury area, 39.9 tons failed to meet the Polish standard requirements (Siuda et al. 2003).

From scant literature data it appears that honey ripening can be accelerated. This can be done under controlled conditions while the honey remains in comb cells. Heated air from 29 to 34°C is used. In capped cells, moisture decreases by 2% and in uncapped ones by 4% within 4 days (Nass 1986).

Due to technical reasons, honey is usually subjected to accelerated ripening after being centrifuged. Raising the temperature of honey above 60°C and decreasing air humidity (Platt and Ellis 1985, Maxwell 1987, Kuehl 1988, Wakhle et al. 1988) can accelerate the process of water evaporation from the surface of honey. Additionally, reduction of air pressure substantially accelerates the process of water removal (Tabouret 1977).

The aim of the study was to determine the conditions of removing water excess from unripe honey and to examine the dynamics of the process.

MATERIAL AND METHODS

The study was conducted in the years 2004-2006, at the Department of Beekeeping Technologies, Apiculture Division, Institute of Pomology and Floriculture in Puławy, Poland.

From each honeybee colony, stationed at a defined pasture, two samples of honey of 200ml each were collected: one of unripe honey and the other of ripe honey. The sample of unripe honey was collected as the nectar flow continued by taking one comb with uncapped honey from a colony. The comb was placed in a small container protected in a polyethylene bag. It was centrifuged in a honey extractor so that only honey from one frame could be extracted. The extracted sample was subjected to an excess of water removal. A sample of in-hive ripe honey was collected from the same colony which had been sampled for unripe honey. The sample was collected from a capped comb in the same manner in which unripe honey had been sampled before. During the 3-year period of the experiment, 79 samples of unripe honey, 79 samples of dehydrated honey and 69 samples of in-hive ripe honey were collected.

For the use of the experiment, a special wooden box, covered with polyethylene foil of 0.2mm thick, was constructed. It was cubicoid-shaped, with a base of 90 x 70 cm and a wall height of 170 cm. The capacity of the box was 1.07m^3 (Phot.). A Chigo® heat pump air dehumidifier, model CFZ0.8BDc, was placed inside the box. The air passed through a filter. The air was then cooled down on the surface of the evaporator to below the dew point, the excess of water undergoing condensation. Subsequently, a much lower moisture level of air was blown into the box. The water removal system caused the moisture content of the air to be lowered without changing the air temperature. The efficiency of the dehumidifier was 0.8l/hr, with an airflow rate of 200m^3/h according to the manufacturer's information. It is the reduction of air humidity in the chamber that allowed the water excess to be removed from the honey.

Centrifuged honey samples to be dehydrated were spread on flat plastic plates 20cm in diameter and of 600-cm^3 capacity. The plates were placed in the box. The layer of honey was 1 cm thick and the surface of each plate was ca. 300cm^2. As the honey was dehydrating, the conditions in the box were monitored using an Oregon Scientific electronic temperature and humidity gauge.

Phot.: Honey dehydrator box – front view.

Unripe honey samples, as well as samples of in-hive ripening honey, were assayed for water content. This was done after being taken from the hive and the water removal-dehydration process had been completed. The dyhydration process was done once in a 12-hour period. Water content was measured using the refractometer method according to the standard PN – 88/A–77626 „Miód Pszczeli" (Honeybee Honey). Honey was classified into types (nectar honey, mixed nectar and honeydew honey, deciduous honeydew honey) by measuring its electric conductivity using the conductometric method according to the standard PN – 88/A–77626 „Miód Pszczeli". For the honeys not included in the standard (borage and raspberry honey), the content of the dominant pollen was assumed to be 10 and 45%, respectively.

The moisture content data for unripe honey, dehydrated honey and naturally rapening honey samples were analyzed statistically by one-way ANOVA and tested for significant differences using Duncan's test at a level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

During the experiment, it was decided that the dehydration process should last 36 hours. The average temperature in the dehydrator box was 28 to 38°C. The variation was caused by changes of temperature in the room where the box was installed. The mean air humidity in the box ranged from 18 to 20% and was characterized by lower variation.

Moisture content of honey during the process of water removal decreased at a very fast rate (Fig. 1). The initial average water content of unripe honeys was 22.9% only to fall by an average of 3.4% after 12 hours of dehydration. Within the following 12 hrs an average of 2.1% of water was removed. This caused the average water content to become stabilized after 24 hrs at below 18%. After 36 hours of dehydration, the average water content of honey was 15.9%. During dehydration, the moisture content of honey decreased by 7%, on average.

Honey extracted from the combs with uncapped cells while the nectar flow continued characterized higher water content at a level above 20% in each case

(Table 1). From among unripe honeys the highest average water content was found in heather honey (26.7%). Unripe borage honey, multifloral honey and oilseed rape honey contained more than 23% of water on average. Moisture averaging 22 to 23% was found in mixed nectar and honeydew honey, broadleaf honeydew honey, raspberry honey and linden honey. In the remaining unifloral honeys the water content was slightly less than 22%.

Subjecting honey to dehydration always resulted in a distinct decrease of water content. As a result of drying, the highest decrease in water content (more than 9%) was found for heather honey. It was mainly due to the high water content of the unripe honey. In dehydrated samples of oilseed rape honey, multifloral honey and broadleaf honeydew honey the average water content ranged from 16 to 17%. Upon dehydration, the water contents of raspberry honey, mixed nectar and honeydew honey and buckwheat honey came within the 15 to 16% range. Less than 15% of water was found in acacia honey and in linden honey.

The process of water removal from unripe honeys resulted in a substantial decrease in their water content. The differences were found to be highly significant for all honey varieties.

Among the honeys harvested in a conventional manner, as it was in the case of dehydrated honeys, heather honey was the highest in moisture. Buckwheat and oilseed rape honey, each had water content above 18%. In mixed nectar and honeydew honey, deciduous honeydew honey, acacia honey, raspberry honey and multifloral honey average water content was found to be between 17 and 18%. In the borage honey and linden honey water content was below 17%.

By comparing data on water content of dehydrated honey and honey extracted when fully ripe, it was found that the average water content in all dehydrated honey varieties was lower. In oilseed rape, raspberry, linden, buckwheat and heather honey ANOVA analysis showed the differences to be highly significant ($p \leq 0.01$). In broadleaf honeydew honey, linden, heather and borage honeys as well as in multifloral honey the differences were not confirmed statistically. There is a tendency in dehydrated honeys to have lower water content.

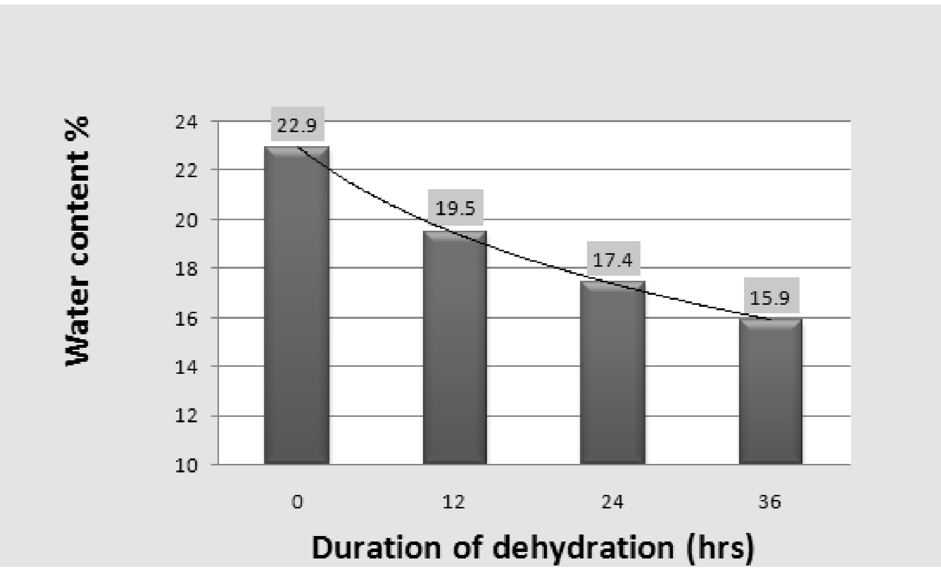

Fig. 1. Changes in water content in honey during the removal of water excess.

Table 1

Dehydration-related changes in water content of honey vs. water content of in-hive ripe honeys (%).

Honey variety	Unripe honeys			Dehydrated honeys			In-hive ripe honeys		
	Number of samples (n)	min – max	Mean($\bar{x}$)	Number of samples (n)	min – max	Mean ($\bar{x}$)	Number of samples (n)	**min – max**	Mean ($\bar{x}$)
Mixed nectar and honeydew	10	20.5 – 28.0	**22.7 B**	10	14.3 – 17.7	**15.8 A**	10	14.3 – 20.0	**17.1 A**
Deciduous honeydew	5	20.9 – 27.5	**22.6 B**	5	16.4 – 17.8	**16.9 A**	5	16.6 – 18.0	**17.3 A**
Oilseed rape	10	20.1 – 27.3	**23.1 C**	10	15.0 – 17.4	**16.2 A**	9	16.2 – 19.3	**18.1 B**
Acacia	5	20.3 – 23.2	**21.9 C**	5	13.1 – 15.3	**14.4 A**	4	16.8 – 19.6	**17.6 B**
Raspberry	10	20.1 – 23.8	**22.2 C**	10	14.7 – 16.5	**15.4 A**	8	16.3 – 18.3	**17.6 B**
Linden	10	20.1 – 25.2	**22.0 C**	10	14.1 – 15.2	**14.6 A**	8	15.9 – 18.2	**16.8 B**
Buckwheat	8	20.1 – 24.5	**21.9 C**	8	15.2 – 16.4	**15.9 A**	6	17.1 – 18.9	**18.3 B**
Borage	5	20.9 – 28.6	**23.9 B**	5	15.0 – 17.7	**16.4 A**	5	15.8 – 17.7	**16.4 A**
Heather	6	21.2 – 40.0	**26.7 B**	6	16.7 – 18.4	**17.5 A**	4	19.1 – 21.0	**20.0 B**
Multifloral	10	20.1 – 29.8	**23.2 B**	10	15.0 – 17.4	**16.7 A**	10	15.2 – 20.4	**17.4 A**
	79	20.1 – 40.0	**22.9 C**	79	13.1 – 18.4	**15.9 A**	69	14.3 – 21.0	**17.6 B**

Values followed by different capital letters A , B and C are statistically different at $p \le 0.01$.

The water content of unripe honeys substantially exceeded the admissible limit determined for honeys in the Rulings of the Ministry of Agriculture and Rural Development and in the Polish standard for honey. During dehydration, the largest decrease in water content occurred within the first 12 hrs of the water removal process. It was probably due to the fact that in the initial stage of dehydration water content of honey was high and honey lost water more readily. As the moisture level in honey decreased, the water loss process decelerated. However, it is difficult to relate the pattern of water removal from honey observed in this study to the results reported by other investigators. First of all, the technical conditions of the experiments are different. In this study, water removal took place at a temperature below 40°C, which is safe for honey quality. In other studies, water was removed at temperature level above 60°C (Platt and Ellis 1985, Maxwell 1987, Kuehl 1988, Wakhle et al. 1988). Additionally, Tabouret (1977) conducted his experiment at reduced air pressure.

With dehydration, the honeys were characterized by water content from 13.1 to 18.4%, average 15.9%. Such a low water content of honey allows for its safe storage. It protects the product against the risk of fermentation even if it has a high count of osmophilic yeast (Lochhead 1933, Stephen 1946). The water content of dehydrated honeys was substantially lower than that found by other investigators in different unifloral honeys (Rychlik and Fedorowska 1965, Rybak 1986, Bogdanov 1990, Persano Oddo and Piro 2004). Dehydrated honeys in this study had lower water content than those obtained in-hive-ripening honeys. The differences, with the exception of borage honey and multifloral honey, are statistically valid. The results for conventionally maturing honeys are, for the most part, in agreement with the data reported by the investigators cited above. In the case of buckwheat honey, water content ranged from 17.1 to 18.9% that is lower than reported by Rychlik and Fedorowska (1965).

The data obtained in this study warrant the effort to construct a device to remove water from honey on a commercial scale.

An additional benefit from using the process in apiaries would be labour reduction. This is because the need to uncap the combs would be eliminated.

CONCLUSIONS

1. The manner and conditions of removing water excess from honey adopted in this study allow for efficiently carrying out the process.
2. As a result of dehydration, there occurs a significant reduction in water content of unripe honeys below the level considered as acceptable for ripe honeys.
3. The method of dehydration of honey used in this study, when adopted to the conditions of commercial apiaries, will allow the reduction of water content of unripe honey to a level that allows it to be safely stored.

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ZMIANY ZAWARTOŚCI WODY W MIODZIE ZACHODZĄCE PODCZAS DOJRZEWANIA W KONTROLOWANYCH WARUNKACH

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Streszczenie

Celem badań było określenie warunków odparowania nadmiaru wody z niedojrzałego miodu i zbadanie dynamiki tego procesu. Materiał do badań stanowiły próbki różnych miodów odmianowych pozyskanych w Oddziale Pszczelnictwa i pasiekach produkcyjnych. W trakcie 3 lat trwania doświadczenia pozyskano do badań 79 próbek miodów niedojrzałych, 79 próbek miodów odwadnianych oraz 69 próbek miodów dojrzewających w ulach. Odwadnianie próbek miodu prowadzono za pomocą kondensacyjnego osuszacza powietrza marki Chigo®. Wydajność wykorzystanego w badaniach urządzenia wg danych producenta wynosiła 0,8 l/h, a przepływ powietrza ok. 200 m^3/h. Osuszacz umieszczono w specjalnej komorze, o kubaturze 1,07 m^3, o drewnianej konstrukcji, pokrytej folią. Początkowa średnia zawartość wody w miodach niedojrzałych wynosiła 22,9%. W ciągu 36 godzin dehydratacji obniżono średnią zawartość wody do poziomu 15,9%.

Słowa kluczowe: miód, zawartość wody, odwadnianie, osuszacz powietrza, dojrzewanie miodu poza ulem.