

## CHANGES ON SACCHARIDE COMPOSITION OF HONEY DURING RIPENING UNDER CONTROLLED CONDITIONS

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### S u m m a r y

An experiment was carried out to study the effect of honey ripening under controlled conditions on the honey's saccharide composition. The experimental materials used for the analysis were the samples of unifloral honeys collected from different apiaries. Analysis were conducted on 79 samples of unripe honeys that were dehydrated in a specially-prepared chamber as well as on 69 samples of honeys from the same apiaries which were allowed to ripe in the hives. The dehydration of the unripe honeys resulted in an increase in the content of reducing sugars that ranged from 3 to 8%. Statistical analysis of the results demonstrated that in all varieties of dehydrated unripe honeys, except for linden honey, the content of the reducing sugars increased to a significant extent. The content of reducing sugars in the dehydrated honeys and in-hive ripening honeys did not differ statistically, with an exception of dehydrated oilseed rape and borage honeys which had a significantly higher content of saccharide. The process of honey dehydration under controlled conditions caused a slight decrease in the content of saccharose in all honey varieties analyzed. The difference observed in its concentration between unripe and dehydrated honeys was around or below 1%.

**Keywords:** honey, dehydration, carbohydrates.

### INTRODUCTION

Previous investigations (Semkiw et al. 2008a) demonstrated the feasibility of conducting the process of honey dehydration under controlled conditions. That process enables reducing the water content of honey to a level, which allows for its safe and long-lasting storage. It was additionally shown that the harvest of unripe honey at the end of nectar flow afforded greater possibilities of obtaining pure varietal honey from the nectar flow of each type. The content of dominant pollen appeared to be significantly higher in the unripe honey than in in-hive ripening honeys, which is quite important

(Semkiw et al. 2008b).

The object of this research work was to determine the saccharide composition of honeys ripened outside the hive.

An in-depth study of the characteristics of domestic unifloral honeys in terms of the content of reducing sugars and saccharose was first presented by Rybak (1986). Reducing sugars (fructose, glucose, turanose, maltose, isomaltose) in nectar honeys constituted, on an average of from 71.4% (in heather honey) to 77.4% (in oilseed rape honey). As compared to the nectar honeys, a significantly lower content of reducing sugars was reported for mixed nectar and honeydew (69.9%) and

honeydew honeys (67.9%). The content of saccharose determined together with melezitose was affected, to a great extent, by the raw honey material. In most of the nectar honeys, the content of saccharose did not exceed by 2%, except for honey from robinia in which saccharose content was up to 10% (7.7% on average) and for honeys from orchards (4.3% on average). In mixed nectar and honeydew honey, the average content of saccharose, determined together with melezitose, accounted for 3.5%, whereas in the honeydew honey it was for 4.3%.

Current regulations applied to determine qualitative parameters of honey (Codex Alimentarius Commission 2001) recommend the implementation of more accurate methods of assaying individual saccharides: fructose, glucose and saccharose. Current regulations recommend using chromatographic techniques: gas chromatography (GC) or high performance liquid chromatography (HPLC). The chromatographic determination of saccharide composition in honey enables the classification of its types. Honeydew honey has a much higher content of raffinose and maltotriose (Rybak-Chmielewska and Szczęśna 2000), as well as lower content of fructose and glucose, than the nectar honeys (Persano Oddo and Piro, 2004). The determination of saccharide composition enables an additional identification of some varieties of honey. High content of fructose are typical of honeys originating from labiate (*Labiatae*), fireweed (*Epilobium*) (Maurizio 1964) or from robinia (Rybak-Chmielewska and Szczęśna 2000, Persano Oddo and Piro 2004). A higher content of glucose in respect to other saccharides is a typical characteristic of oilseed rape honey (Maurizio 1964, Persano Oddo and Piro 2004). In contrast, buckwheat honey is characterized by a lack of trisaccharides (raffinose,

maltotriose and melezitose) (Rybak-Chmielewska and Szczęśna 2000).

The identification of the saccharide content of honey enables to determine the strict control criteria of the quality of that product. Based on those assays, both the EU Directive (Council Directive 2002) and the global standard (Codex Alimentarius Commission 2001) stipulated the following requirements: the content of monosaccharides (expressed as the sum of fructose and glucose) should not be lower than 60% in nectar honey and 45% in honeydew honey. The content of saccharose should not exceed 5% in nectar honey and honeydew honey, except for those in which its content may naturally reach up to 10%, e.g. in honeys from robinia acacia (*Robinia pseudoacacia* L.), lucerne (*Medicago sativa* L.), firewood Banksia (*Banksia menziesii* R.B.), sweetvetch (*Hedysarum* L.), eucalyptus (*Eucalyptus camandulensis* D.), leatherwood (*Eucryphia lucida* B.), Citrus spp., and even up to 15% in honeys from lavender (*Lavendula* spp.) and borage (*Borago officinalis* L).

Krauze and Zalewski (1991) determined the content of saccharides in domestic varieties of honey (oilseed rape, heather, robinia, linden and honeydew honey) by means of the gas chromatography. In nectar honeys, reducing monosaccharides constituted an average of from 71.5% (heather honey) to 77.3% (oilseed rape honey). Honeydew honeys were characterized by a significantly lower content of reducing sugars (64.9%) as compared to the nectar honeys. The mean content of saccharose in nectar honeys ranged from 0.38% (in linden honey) to 2.3% (in robinia honey), whereas in honeydew honey from 0.35 to 4.41%. In turn, Rybak-Chmielewska and Szczęśna (2000), mentioned the composition of reducing sugars in domestic

honeys from 57.78 to 76.74%. In all honey varieties, except for linden honey and honeydew honey, the content of the reducing sugars exceeded 62%. The highest mean content of the saccharides was observed in buckwheat honey (71.9%) and the lowest in linden honey (61.68%). A very low content of saccharose (< 0.2%) was reported in heather and buckwheat honeys. The highest saccharose content was found in robinia honey and honeydew honey, i. e. 1.12 and 0.71%, respectively. For multifloral honeys, Rybak-Chmielewska and Szczęsna (2003) recommended the following requirements: the content of monosaccharides - not less than 65%, the content of saccharose - not higher than 3%, and the content of disaccharides - not higher than 10%. The content of trisaccharides in nectar honeys is usually low. Higher quantities of trisaccharides are typical to honeydew honeys (Szczęsna et al. 2003).

A few hundred samples of linden honey originating from the south of Europe were analyzed by Persano Oddo and Piro (2004). The results indicated that a few of them were characterized by a higher content of saccharose (over 5%) and a lower content of reducing monosaccharides (below 60%).

An important parameter for determining the quality and authenticity of honey is the ratio of fructose to glucose content. In the case of honeydew honey, its average value was 1.18, and in nectar honey it averaged 1.19. The lowest values of that parameter were reported for rape honey (0.98), and the highest ones (ca. 1.4) for robinia honeys and multifloral honeys (from 1 to 1.35) (Rybak-Chmielewska, 2007b).

## MATERIAL AND METHODS

The research was conducted from 2004 to 2006, at the Apiculture Division, Research Institute of Pomology and

Floriculture in Puławy. Honey samples to be analyzed were collected from the experimental apiaries of the Institute and from commercial apiaries located across the country (Semkiw et al., 2008b).

Two samples of honey (one from unripe and the other from ripe honey) were collected from each honeybee colony stationed at a specified forage site, both in the quantity of ca. 200 ml. The sample of unripe honey was harvested by removing one comb with uncapped honey from a honeybee colony while the nectar flow was still in progress. The comb with honey was centrifuged in a honey extractor in a special cassette protected with a polyethylene bag so that only honey from one frame could be harvested during centrifugation. The collected sample was dehydrated. The sample of in-hive ripe honey was harvested from the same colony from where unripe honey was collected. It was harvested from a capped comb, using the same procedure as that of unripe honey after removing the cappings (Semkiw et al. 2008a).

The saccharides composition was determined with the HPLC method (Bogdanov et al. 1997), in modification of the Bee Products Quality Testing Laboratory (Rybak - Chmielewska and Szczęsna 2003, Rybak-Chmielewska 2007a). The identification of saccharides in honey was conducted by comparing the retention times of particular saccharides in a standard solution and in a sample solution (qualitative analysis). The quantitative analysis was carried out by comparing peak areas, solution volume and masses of individual saccharides in a standard solution and peak areas of the same saccharides in the sample solution, with the method of an external standard.

Results obtained for a particular carbohydrates in unripe, dehydrated and in-hive ripening honeys were analyzed statistically with one-way analysis of variance evaluated with DUNCAN's test at

a significance level of  $\alpha = 0.05$ .

During the period of 3 years of the experiment, 79 samples of unripe honeys, 79 samples of dehydrated honeys and 74 samples of in-hive ripening honey samples were collected. Palynological analyses did not confirm the expected honey variety in the case of a few samples of honey ripening in a hive. For this reason, 69 instead of 74 samples of those honeys were taken for analyses of saccharide composition.

## RESULTS

The percentage content of monosaccharides (fructose and glucose) in the honey examined ranged from 55.08 to 79.92% (Table 1). The content of monosaccharides in the unripe honeys ranged from 55.08 to 77.59%; in the dehydrated honeys from 59.91 to 79.92%; and in the in-hive fully ripen honeys from 59.95 to 79.95%.

Among the unripe honeys, the lowest content of fructose and glucose was reported for linden honey and the highest for buckwheat honey. Dehydration of the unripe honeys elicited an increase in the content of monosaccharides that ranged from 2.43 to 7.37%. In the unripe honeys, the greatest increase in the monosaccharides content was found in heather, robinia, raspberry, mixed nectar and honeydew honey, oilseed rape and borage honeys. A slight increase in the content of monosaccharides upon dehydration was observed in buckwheat and multifloral and deciduous honeydew honeys and the least increase in linden honey. In contrast, the highest content of monosaccharides was found in raspberry and buckwheat honeys, and the lowest in linden, deciduous honeydew and borage honeys. The statistical analysis of the results demonstrated an increase to a significant extent in the content of monosaccharides in all honeys, except for

linden honey as a result of dehydration of unripe honeys.

The content of monosaccharides in the honeys ripening in hives was similar to the most of the varieties of dehydrated honeys. In dehydrated honeys and in the conventionally-produced honeys, the highest content of monosaccharides was observed in raspberry and buckwheat honeys. The lowest content of monosaccharides was found in linden and borage honeys as well as in deciduous honeydew honey. The total content of fructose and glucose in those varieties of honey after dehydration and of those harvested conventionally did not differ significantly.

Analysis of samples of honey, showed the range of fructose:glucose ratio on an average from 1.02 to 1.51, (Table 2). The lowest fructose:glucose ratio was found in oilseed rape honey, whereas the highest in robinia and heather honeys. The ratio of these monosaccharides in the other varieties of honey ranged from 1.12 (unripe deciduous honeydew honey) to 1.19 (in-hive ripening raspberry honey). The statistical analysis of the results did not demonstrate any significant differences between honey varieties harvested with different methods.

Extreme values of the content of disaccharides - turanose, maltose and isomaltose (reducing sugars) and trehalose (non-reducing sugar), in the honey samples analyzed ranged from 0.98 to 9.78% (Table 3). Among the unripe honeys (not subjected to dehydration), the lowest content of those saccharides was determined in raspberry and oilseed rape honeys, whereas the highest ones in deciduous honeydew, and mixed nectar and honeydew honeys. In the dehydrated honeys, the lowest content of disaccharides was found for the same varieties as above, while the highest sum of disaccharides was assayed in mixed nectar and honeydew, and

Table 1

Comparison of changes in the content of monosaccharides (glucose and fructose) between: unripe, dehydrated, in-hive ripening unifloral honeys (%).

Honey variety	Number of samples (n)	Unripe honeys		Dehydrated honeys		In-hive ripening honeys		
		Range		Range		Number of samples (n)	Range	
		min - max	Mean ( $\bar{x}$ )	min - max	Mean ( $\bar{x}$ )		min - max	Mean ( $\bar{x}$ )
Mixed nectar and honeydew	10	59.96 - 72.21	63.42 A	63.17 - 74.03	68.84 B	10	65.02 - 77.8	70.61 B
Deciduous honeydew	5	62.23 - 65.08	64.10 A	65.97 - 68.93	67.33 B	5	68.02 - 70.23	68.86 B
Oilseed rape	10	62.03 - 74.76	67.85 a	67.22 - 79.26	73.23 b	9	62.33 - 74.39	69.17 ab
Robinia	5	58.91 - 68.68	65.17 a	65.87 - 74.65	71.14 b	4	62.9 - 72.27	69.13 ab
Raspberry	10	68.79 - 77.59	72.43 A	76.76 - 79.46	77.88 B	8	75.7 - 79.75	76.48 B
Linden	10	55.08 - 71.21	60.30 a	59.91 - 72.89	62.73 a	8	59.95 - 67.08	63.17 a
Buckwheat	8	70.13 - 76.53	72.48 a	73.84 - 79.92	76.46 b	6	72.6 - 75.97	74.61 b
Borage	5	59.32 - 67.34	63.71 a	63.62 - 70.70	67.73 b	5	64.1 - 71.94	66.96 b
Heather	6	55.3 - 68.72	64.86 A	66.32 - 75.81	72.23 B	4	69.26 - 70.9	69.96 AB
Multifloral	10	66.06 - 74.07	70.89 a	68.81 - 76.55	74.15 b	10	66.4 - 78.43	73.21 ab

Different letters in rows a and b are statistically significant differences at  $p \leq 0.05$ .

Different letters in rows A and B are statistically significant differences at  $p \leq 0.01$ .

Table 2

Comparison of fructose and glucose ratio between: unripe, dehydrated, in-hive ripening unifloral honeys (%).

Honey variety	Number of samples (n)	Unripe honeys		Dehydrated honeys		In-hive ripening honeys		
		Mean ( $\bar{x}$ )	SD	Mean ( $\bar{x}$ )	SD	Number of samples	Mean ( $\bar{x}$ )	SD
Mixed nectar and honeydew	10	1.12 a	0.02	1.13 a	0.01	10	1.14 a	0.02
Deciduous honeydew	5	1.14 a	0.01	1.14 a	0.01	5	1.13 a	0.03
Oilseed rape	10	1.02 a	0.06	1.03 a	0.06	9	1.09 a	0.02
Robinia	5	1.45 a	0.11	1.45 a	0.11	4	1.51 a	0.16
Raspberry	10	1.18 a	0.06	1.19 a	0.05	8	1.19 a	0.03
Linden	10	1.12 a	0.02	1.15 a	0.03	8	1.15 a	0.01
Buckwheat	8	1.13 a	0.03	1.14 a	0.02	6	1.15 a	0.01
Borage	5	1.14 a	0.03	1.16 a	0.01	5	1.14 a	0.02
Heather	6	1.28 a	0.06	1.29 a	0.05	4	1.25 a	0.06
Multifloral	10	1.12 a	0.09	1.13 a	0.11	10	1.16 a	0.03

Different letters in rows a and b are statistically significant differences at  $p \leq 0.05$ .  
SD - standard deviation

Table 3

Comparison of changes in the content of disaccharides between: unripe, dehydrated, in-hive ripening unifloral honeys (%).

Honey variety	Number of samples (n)	Unripe honeys		Dehydrated honeys		In-hive ripening honeys		
		Range	Mean ( $\bar{x}$ )	Range	Mean	Number of samples (n)	Range	Mean ( $\bar{x}$ )
		min - max		min - max			min - max	
Mixed nectar and honeydew	10	4.15 - 6.13	5.70 A	5.75 - 8.36	7.39 B	10	3.47 - 8.36	5.05 A
Deciduous honeydew	5	4.57 - 6.62	6.03 B	4.65 - 6.82	6.46 B	5	3.72 - 4.77	4.34 A
Oilseed rape	10	0.98 - 5.21	2.82 A	1.30 - 6.28	3.83 A	9	4.51 - 6.29	5.33 B
Robinia	5	4.8 - 5.04	4.79 A	5.66 - 6.58	5.97 B	4	6.52 - 7.64	7.20 C
Raspberry	10	1.57 - 2.97	2.55 A	2.24 - 4.06	3.42 B	8	2.91 - 4.45	3.64 B
Linden	10	3.47 - 6.22	5.20 A	4.20 - 9.78	7.04 B	8	6.54 - 8.27	7.61 B
Buckwheat	8	1.63 - 6.11	3.66 a	3.87 - 7.26	5.28 b	6	4.53 - 7.02	5.56 b
Borage	5	4.98 - 5.74	5.24 A	5.99 - 7.85	6.89 B	5	5.23 - 7.38	6.09 AB
Heather	6	1.09 - 5.54	3.81 a	2.09 - 6.72	4.73 ab	4	2.34 - 8.85	6.88 b
Multifloral	10	1.4 - 7.06	4.02 a	1.8 - 7.57	4.64 a	10	2.39 - 8.12	5.85 a

Different letters in rows a and b are statistically significant differences at  $p \leq 0.05$ .  
Different letters in rows A, B and C are statistically significant differences at  $p \leq 0.01$ .

linden honeys. A slightly different dependency was noted for the in-hive ripening honeys. The raspberry honey and deciduous honeydew honey had the lowest, whereas linden and robinia honeys had the highest content of disaccharides.

After the dehydration process, a significant increase in the content of the disaccharides was observed in linden, mixed nectar and honeydew, borage, buckwheat, robinia and raspberry honeys. In the other honey varieties, although the differences were statistically insignificant, yet in each case the percentage of disaccharides after dehydration increased. The conventionally-produced robinia and oilseed rape honeys are the only honeys which when compared with the dehydrated honeys, contained significantly higher quantities of disaccharides. Significantly lower content of those saccharides (out of the in-hive ripening honeys as compared to the same but dehydrated honey varieties) was noted in mixed nectar and honeydew and deciduous honeydew honeys. In the case of the latter the content of disaccharides was lower than that reported in the unripe honeys. Other honey varieties harvested with different methods (unripe, dehydrated and conventional) did not differ significantly in terms of disaccharide content.

The content of reducing sugars (fructose, glucose, turanose, maltose, isomaltose) in the honeys examined fluctuated between 55.86 and 82.64%. The content of reducing sugars in the unripe honeys ranged from 55.86 to 79.19%; whereas from 61.40 to 82.64% in the dehydrated honeys and from 66.72 to 81.82% in the honeys harvested after full ripen in hive (Table 4).

Among the unripe honeys, the lowest content of reducing sugars was found in linden honey, whereas the highest was in buckwheat honey. Dehydration of the unripe honeys caused an increase in the

content of reducing sugars that ranged from 3 to 8%. The highest increase in their content was observed in heather, robinia, mixed nectar and honeydew, oilseed rape and raspberry honeys. A slightly lesser increase in the content of those sugars as a result of dehydration was found in buckwheat, linden and borage honeys, and the least in multifloral honey and deciduous honeydew honey. The highest content of reducing sugars was found in honeys of raspberry and buckwheat, and the lowest was in honeys of linden, borage and deciduous honeydew honey. The statistical analysis of the results demonstrated an increased to a significant extent in the content of reducing sugars in all varieties, except for linden honey as a result of the dehydration of unripe honey.

The content of reducing sugars in most of the varieties of the in-hive ripening honeys was similar to dehydrated honeys. An exception were honeys from oilseed rape, robinia and buckwheat, whose ripening in a hive caused a reduction of these sugars content by 2 - 3%. In case of the dehydrated honeys, as well as in the conventional ones, the highest content of reducing sugars was recorded in raspberry and buckwheat honeys. The lowest concentrations of those sugars were determined in linden, borage and deciduous honeydew honeys. The content of reducing sugars in the dehydrated and conventionally produced honey did not differ statistically with an exception of rape and borage honey which contained significantly higher content of reducing sugars after dehydration.

The content of saccharose in unripe honeys examined, ranged from 0 to 19.97% which was not detected in single samples of raspberry, buckwheat, heather or multifloral honeys (Table 5). However, its highest content was reported in one sample of linden honey. Higher content of saccharose was also demonstrated in

Table 4

Comparison of changes in the content of reducing sugars between: unripe, dehydrated, in-hive ripening unifloral honeys (%).

Honey variety	Number of samples (n)	Unripe honeys			Dehydrated honeys			In-hive ripening honeys		
		Range		Mean ( $\bar{x}$ )	Range		Mean ( $\bar{x}$ )	Range		Mean ( $\bar{x}$ )
		min - max	min - max		min - max	min - max				
Mixed nectar and honeydew	10	63.94 - 74.77	67.23 A	67.45 - 77.71	73.93 B	68.16 - 80.16	74.06 B			
Deciduous honeydew	5	65.46 - 69.78	68.25 A	70.31 - 72.67	71.80 B	70.30 - 72.80	72.20 B			
Oilseed rape	10	63.65 - 76.47	69.91 A	71.36 - 80.76	76.07 B	66.72 - 78.50	73.06 A			
Robinia	5	62.60 - 72.20	68.59 A	70.74 - 78.98	76.04 B	67.63 - 77.84	74.16 B			
Raspberry	10	70.68 - 79.19	74.29 A	78.43 - 82.21	80.35 B	78.40 - 81.82	79.11 B			
Linden	10	56.43 - 74.69	63.88 a	61.40 - 80.06	68.99 a	67.31 - 72.77	68.74 a			
Buckwheat	8	73.28 - 77.48	74.88 A	78.60 - 82.64	80.27 B	76.03 - 80.13	78.50 B			
Borage	5	63.57 - 71.35	67.53 a	68.03 - 76.40	72.80 b	67.94 - 77.46	71.50 a			
Heather	6	55.86 - 71.47	67.42 A	71.14 - 78.36	75.48 B	70.92 - 76.06	74.39 B			
Multifloral	10	67.13 - 77.31	73.70 A	71.82 - 81.05	77.03 B	72.22 - 80.86	77.42 B			

Different letters in rows a and b are statistically significant differences at  $p \leq 0.05$ .  
 Different letters in rows A and B are statistically significant differences at  $p \leq 0.01$ .

Table 5

Comparison of changes in the content of saccharose between unripe, dehydrated, in-hive ripening unifloral honeys (%).

Honey variety	Number of samples (n)	Unripe honeys		Dehydrated honeys		In-hive ripening honeys		
		Range	Mean ( $\bar{x}$ )	Range	Mean ( $\bar{x}$ )	Number of samples (n)	Range	Mean ( $\bar{x}$ )
		min - max		min - max			min - max	
Mixed nectar and honeydew	10	0.43 - 5.64	<b>3.06 a</b>	0.19 - 4.23	<b>2.01 a</b>	10	0.42 - 4.56	<b>1.93 a</b>
Deciduous honeydew	5	1.56 - 2.48	<b>2.08 a</b>	1.48 - 2.26	<b>1.93 a</b>	5	1.21 - 3.22	<b>2.14 a</b>
Oilseed rape	10	0.29 - 1.57	<b>0.85 a</b>	0.08 - 1.31	<b>0.62 a</b>	9	0.06 - 2.19	<b>0.77 a</b>
Robinia	5	1.97 - 7.66	<b>3.84 a</b>	1.08 - 6.51	<b>3.00 a</b>	4	0.99 - 5.74	<b>2.50 a</b>
Raspberry	10	0.00 - 1.55	<b>0.51 a</b>	0.00 - 1.37	<b>0.46 a</b>	8	0.00 - 0.52	<b>0.31 a</b>
Linden	10	1.02 - 19.97	<b>10.64 a</b>	0.91 - 16.83	<b>9.34 a</b>	8	3.10 - 15.26	<b>8.62 a</b>
Buckwheat	8	0.00 - 0.12	<b>0.03 a</b>	0.00 - 0.12	<b>0.02 a</b>	6	0.00 - 0.27	<b>0.05 a</b>
Borage	5	5.12 - 8.53	<b>6.09 a</b>	3.95 - 8.39	<b>6.05 a</b>	5	5.04 - 12.33	<b>8.50 a</b>
Heather	6	0.00 - 4.87	<b>1.47 a</b>	0.00 - 3.16	<b>0.89 a</b>	4	0.00 - 3.12	<b>0.85 a</b>
Multifloral	10	0.00 - 1.58	<b>0.30 a</b>	0.00 - 1.38	<b>0.28 a</b>	10	0.00 - 1.59	<b>0.50 a</b>

Different letters in rows a and b are statistically significant differences at  $p \leq 0.05$ .

honeys of borage (5.12 - 8.53%) and robinia (1.97 - 7.66%). Less than 1% of saccharose, on average, was noted in multifloral, raspberry and oilseed rape honeys.

The analysis of results for saccharose content in a particular honey variety did not demonstrate any statistically significant differences between the unripe, dehydrated and fully ripe in-hive honeys. Hence, only characteristic tendencies may be noted for changes in the parameter examined in particular types and varieties of honey. This is due to the fact that the process of honeys ripening under controlled conditions elicited a slight reduction in the content of saccharose in all honeys analyzed. The differences in saccharose content between unripe and dehydrated honeys reached around or below 1%. The highest decrease in the content of saccharose upon dehydration was noted in linden honey (1.30%) and the smallest decrease (0.01%)

in buckwheat honey.

Borage and multifloral honeys as well as deciduous honeydew honey harvested conventionally contained a higher amount of saccharose as compared to honeys of the same varieties harvested which were produced as unripe and dehydrated. Lower content of saccharose was observed in mixed nectar and honeydew, raspberry, linden and heather honeys in respect to the unripe and dehydrated honey. The traditionally harvested oilseed rape honey had a higher mean content of saccharose as compared to the dehydrated honey and a lower mean content of saccharose as compared to the unripe honey.

The content of trisaccharides (melezitose and erlose in particular) in the honeys examined ranged from 0 to 3.76% (Table 6). Melezitose was not detected in any of the samples of raspberry honey, whereas its trace quantities were recorded in buckwheat and robinia honeys. The

Table 6

Comparison of changes in the content of trisaccharides between unripe, dehydrated, in-hive ripening unifloral honeys (%).

Honey variety	Number of samples (n)	Unripe honeys		Dehydrated honeys		In-hive ripening honeys		
		Range	Mean	Range	Mean	Number of samples (n)	Range	Mean
		min - max		min - max			min - max	
Mixed nectar and honeydew	10	0 - 1.78	<b>0.19 a</b>	0 - 2.17	<b>0.29 a</b>	10	0 - 0.47	<b>0.38 a</b>
Deciduous honeydew	5	0.013-1.70	<b>1.18 a</b>	0.20 - 1.75	<b>1.26 a</b>	5	0.015 - 1.78	<b>1.32 a</b>
Oilseed rape	10	0 - 0.95	<b>0.32 a</b>	0 - 0.83	<b>0.26 a</b>	9	0 - 0.81	<b>0.32 a</b>
Robinia	5	0 - 0.24	<b>0.14 a</b>	0 - 0.25	<b>0.19 a</b>	4	0 - 0.25	<b>0.17 a</b>
Raspberry	10	0	<b>0</b>	0	<b>0</b>	8	0	<b>0</b>
Linden	10	0.03 - 1.30	<b>0.66 a</b>	0 - 1.51	<b>0.74 a</b>	8	0.11 - 1.31	<b>0.94 a</b>
Buckwheat	8	0 - 0.42	<b>0.10 a</b>	0 - 0.51	<b>0.15 a</b>	6	0 - 0.62	<b>0.11 a</b>
Borage	5	0.74 - 1.02	<b>0.92 a</b>	0 - 1.09	<b>0.90 a</b>	5	0.97 - 1.44	<b>1.20 a</b>
Heather	6	0 - 3.72	<b>1.28 a</b>	0 - 3.76	<b>1.29 a</b>	4	0 - 3.12	<b>0.85 a</b>
Multifloral	10	0 - 0.69	<b>0.19 a</b>	0 - 0.69	<b>0.20 a</b>	10	0 - 0.42	<b>0.26 a</b>

Different letters in rows a and b are statistically significant differences at  $p \leq 0.05$ .

highest content of trisaccharides was determined in honeydew as well as in heather, borage and linden honeys. The findings of the study did not demonstrate any differences in content of trisaccharides between honeys obtained under various experimental combinations.

## DISCUSSION

According to the current standards (EU Council Directive 2002, Codex Alimentarius Commission 2001), the content of monosaccharides should not be lower than 60% in nectar honey and 45% in honeydew honey. The content of saccharose should not exceed 5% in nectar and honeydew honeys, except for the honeys of robinia (*R. pseudoacacia*), lucerne (*M. sativa*), firewood Banksia (*B. menziesii*), sweetvetch (*Hedysarum*), eucalyptus (*E. camandulensis*), leatherwood (*E. lucida*), and citrus (*Citrus* spp.) in which the admissible level of

monosaccharides accounts for up to 10%, and even up to 15% in honeys of lavender (*Lavendula* spp.) and borage (*B. officinalis*).

In most cases, the honeys examined met the above-mentioned criteria with an exception of only some samples of unripe linden honey, in which the content of monosaccharides was below 60%. Dehydration, however, caused an increase in the content of these sugars by a few percent, thus allowing the honeys to met the stipulated criterion. In the case of the other honey varieties, the assayed content of reducing sugars was similar to the results obtained earlier by Rybak (1986), Krauze and Zalewski (1991) as well as Rybak-Chmielewska and Szczęśna (2000).

In respect to the content of fructose and glucose, the honeys examined in the study met the criteria stipulated by other authors (Rybak-Chmielewska 2007b). A

typical percentage prevalence of fructose over glucose was confirmed in the case of robinia honey, whereas the fructose:glucose ratio was close to being equal in oilseed rape honey.

The linden honey assayed in the study was additionally characterized by a saccharose content being considerably higher than the admissible level stipulated in the standard. In the dehydrated honeys, the content of saccharose accounted for 9.3% on average, whereas in the conventional honeys it was 8.6%. This content was also much above the values reported in other investigations. In a study by Krauze and Zalewski (1991), reported the content of saccharose in linden honey at a level of 0.38%, whereas Rybak (1986) found this at level of ca. 1.5%. The results obtained in this current study correspond with the findings of Persano Oddo and Piro (2004), who observed the content of saccharose, above than the admissible level by 5% in a few samples of linden honey. The high content of saccharose found in the current study may be due to the fact that the honeys analyzed were fresh honey or honey stored for a short period of time at a temperature of ca. +4°C. The other researchers analyzed honeys usually after a longer period of storage, during which enzymes contained in the honey converted saccharose into monosaccharides. Another likely reason for the higher content of saccharose in the linden honey may be the intensive nectar secretion of linden over the experimental period. High, daily gains of nectar in hives did not allow the honeybees to sufficiently enrich the harvested nectar in an appropriate quantity of enzymes. As in the previous study (Rybak-Chmielewska and Szczęśna 2000), a very low content of saccharose was determined in buckwheat honey and a higher level in robinia honey, although it was significantly lower than the admissible level.

Generally, the study confirmed the thesis formulated earlier by Szczęśna et al. (2003) that the contribution of trisaccharides in nectar honeys, except for borage honey, is usually small and that their higher concentrations are typical of honeydew honeys. The higher content of trisaccharides in nectar heather and linden honeys, determined in the current study, may be explained by a high content of honeydew in the honey. The honeydew often occurs during nectar secretion of linden and heather. Over the experimental period in the years 2005 and 2006, deciduous honeydew secretion began as early as at the end of oilseed rape forage and continued practically until the end of the season. It seems that a slightly higher (from 0.74 to 1.44) content of trisaccharides in the honey of borage, which did not result from a honeydew admixture, is probably a variety-specific characteristics of that honey.

The findings of the studies carried out so far (Semkiw et al. 2008a, Semkiw et al. 2008b), as well as the results obtained in the reported study proved that the process of artificial ripening of honey followed out the method in this study has no negative effects on the quality of honey. A subsequent studies will be carried out to elucidate the effect of artificial ripening of honey on the changes in the content of free fatty acid, activity of  $\alpha$  - amylase, as well as content of hydroxymethylfurfural in honey. Findings of the superior results in successive studies will provide the solution for the problem of artificial ripening of honey as well as estimation of the benefits resulting from the use of dehydration in apiaries for practical beekeeping.

## CONCLUSIONS

1. The process of ripening of different varieties of honey under controlled conditions enables to obtain a product in

which the content of saccharides meets stipulated quality criteria.

2. During ripening under controlled conditions, the content of reducing sugars increased in all honey varieties, whereas that of saccharose negligibly decreased. In contrast, the content of trisaccharides remain without any significant changes.

3. The fructose:glucose ratio also remains unchanged in all honey varieties (unripe, dehydrated and in-hive ripe).

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### ZMIANY W SKŁADZIE CUKRÓW W MIODZIE PODCZAS JEGO DOJRZEWANIA W KONTROLOWANYCH WARUNKACH

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**S t r e s z c z e n i e**

Celem badań było określenie wpływu dojrzewania miodu w kontrolowanych warunkach na skład cukrów. Materiał badawczy stanowiły próbki miodów odmianowych pozyskanych z różnych pasiek. Analizy przeprowadzono na 79 próbkach miodów niedojrzałych, które poddano odwadnianiu w przygotowanej do tego celu komorze oraz na 69 próbkach miodów dojrzewających w ulach. Proces dehydratacji niedojrzałych miodów spowodował zwiększenie zawartości cukrów redukujących w granicach od 3 do 8%. Opracowanie statystyczne wyników wykazało, że na skutek odwadniania niedojrzałych miodów udział cukrów redukujących we wszystkich odmianach miodu, z wyjątkiem miodu lipowego, zwiększył się w sposób istotny. Zawartość cukrów redukujących w miodach odwadnianych i pozyskanych w sposób konwencjonalny nie różniła się statystycznie, wyjątek stanowiły miody odwadniane rzepakowe i ogórecznikowe, w których stwierdzono istotnie więcej badanych cukrów. Proces dehydratacji miodów w warunkach kontrolowanych spowodował nieznaczne zmniejszenie się zawartości sacharozy we wszystkich odmianach miodu. Stwierdzone różnice w zawartości tego cukru pomiędzy miodami niedojrzałymi a odwadnianymi wynosiły około lub poniżej 1%.

**Słowa kluczowe:** miód, dehydratacja, węglowodany.