

Characteristic parameters of honey wines and dessert meads

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Abstract: The aim of this study was to evaluate the chemical composition of 17 samples of mead originating from the Czech Republic. The samples included honey wines (made only from water and honey) and dessert meads which were treated mainly by the addition of sugar or alcohol. The following chemical parameters were analysed: ethanol, sugar-free extract, hydroxymethylfurfural (HMF), sugars (monosaccharides, disaccharides), organic acids, assimilable nitrogen, and polyphenols. Substantial differences were found between samples: *i*) the content of glucose and fructose was 2.5–113.1 g L⁻¹ and 17.3–136.3 g L⁻¹, respectively; *ii*) the HMF content ranged from 1.0 mg L⁻¹ to 87.7 mg L⁻¹. The most abundant organic acids were lactic acid (average 1.0 g L⁻¹), gluconic acid (0.6 g L⁻¹), and acetic acid (0.4 g L⁻¹); the amount of phenolic compounds was 151.9–385.3 mg gallic acid equivalent (GAE) L⁻¹. Honey wines typically contained turanose (2.0–7.6 g L⁻¹) and trehalose (1.1–10.1 g L⁻¹), while dessert mead was characterised by an increased sucrose content (up to 76.5 g L⁻¹).

Keywords: alcoholic beverages; fermentation; hydroxymethylfurfural; organic acids; polyphenols; sugars

Mead (also known as honey wine) is a traditional alcoholic beverage prepared by fermenting a honey solution with different proportions of honey and water. Other ingredients, primarily fruits, spices, and herbs, are added to traditional mead recipes. The chemical composition of mead depends mainly on the type of honey used and the amount of other ingredients. Conditions during fermentation (concentration of honey solution, type of yeast, etc.) also play an important role (Akalin et al. 2017; Gaglio et al. 2017). The final ethanol content is usually from 8% to 18% (v/v) (Navrátil et al. 2001). Mead is known for its variable composition. Its most important compounds include sugars, organic acids, minerals, polyphenols, flavonoids, and tannins (Slobodníková et al. 2016; Akalin et al. 2017; Comunian et al. 2017). In the last few years, a number of studies

have been published focusing on important parameters in mead production (fermentation rate, effect of temperature, amount of nutrients, yeast strain, etc.) (Gomes et al. 2013; Iglesias et al. 2014; Cuenca et al. 2016; Sroka and Satora 2017; Schwarz et al. 2020). In contrast, less information is available on the chemical composition of mead (Peepall et al. 2019; Pereira et al. 2019).

The content of residual sugars significantly contributes to the overall composition of mead, which affects the quality and taste of the final product. Gomes et al. (2013) reported that consumers prefer mead with a significantly sweeter taste. Glucose and fructose are dominant monosaccharides in honey and are therefore also present in large quantities in mead (Švecová et al. 2015). Organic acids are another important group of compounds that significantly affect the sensory

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properties of alcoholic beverages (Mato et al. 2005). Acetic acid and formic acid have been confirmed as the major ones in mead (Sroka and Tuszyński 2007; Šmogrovičová et al. 2012). Other important acids include succinic acid which appears to be essential for the control of the fermentation process (Hernández et al. 2015). The presence of honey significantly affects the content of phenolic compounds in mead. Published studies (Švecová et al. 2015) report that the addition of other raw materials (fruit juice, herbal extracts, etc.) contributes to a higher content of phenolic compounds. In addition to nutritionally positive substances, some undesirable substances can also be found in mead, such as hydroxymethylfurfural (HMF).

Since the end of 2018, there have been significant legislative changes in the labelling of mead in the Czech Republic, as new Decree No. 248/2018 Coll. was issued (Vyhláška č. 248/2018 Sb.). This Decree newly distinguishes traditionally produced mead (honey wine) from mead with added alcohol or sugar (dessert mead). No additional alcohol, sugar, flavourings, and colourings may be added to honey wine; on the contrary, dessert mead may contain these additives. Some neighbouring European countries have a more sophisticated classification of mead. In Poland, in compliance with their legislation, it is possible to classify products into four classes depending on the ratio of water and honey, sugar and ethanol content [Act of 2011 No. 120, item 690 (Ustawa Dz. U. 2011 Nr 120 poz. 690)]. In Slovakia, the issue of mead production is enshrined in Decree No. 158/2016 Coll. (Vyhláška č. 158/2016 Z. z.), which defines that honey and water should be the main raw materials for the production of mead. Only additions of fruit juices, herbal extracts, and spices are allowed. European legislation regulates the use of additives in the production of mead and stipulates requirements for distillates made from honey solution (honey spirit) and spirits with added fermented honey mash (honey nectar, mead nectar) [Regulation (EU) No. 1129/2011 of November 2011 amending Annex II to Regulation (EC) No. 1333/2008 of the European Parliament and of the Council by establishing a Union list of food additives; Regulation (EU) No. 2019/787 of the European Parliament and of the Council of April 2019 on the definition, description, presentation and labelling of spirit drinks, the use of the names of spirit drinks in the presentation and labelling of other foodstuffs, the protection of geographical indications for spirit drinks, the use of ethyl alcohol and distillates of agricultural origin in alcoholic beverages, and repealing Regulation (EC) No. 110/2008].

The aim of this study was to evaluate the composition of mead available on the Czech market using the legislative parameters and the content of other selected compounds. This study is the first work that deals with the determination of characteristic parameters for the distinction between honey wines and dessert mead.

MATERIAL AND METHODS

Material

A total of 17 samples of mead originating from the Czech Republic (purchased in brick and mortar stores) were analysed. Both, honey wines (11 samples; 1H–11H) and dessert meads (6 samples; 12D–17D) were represented. Honey wines contained only honey and water. Dessert mead also contained the following ingredients: sugar, alcohol, herbal extracts, wine, hops, caramel, and citric acid. Samples were obtained from the following producers: 1H (Pleva), 2H (Medovíno s.r.o.), 3H (Vorlíčkovo Včelařství), 4H (Klát s.r.o.), 5H (Apifarm), 6H (Medařství Nová Říše), 7H (Včelí farma Vostoupal), 8H (Bašta), 9H (Včelařství Babákov), 10H (Medovinka s.r.o.), 11H (Tomka), 12D (Bee Research Institute VÚV s.r.o.), 13D (Halada), 14D (Včelnex s.r.o.), 15D (Medovinka s.r.o.), 16D (Včelpo s.r.o.), and 17D (L'OR special drinks s.r.o.).

Gallic acid, 5-hydroxymethylfurfural, Folin-Ciocalteu reagent, bis-tris-propane (BTP), hydroxyethylcellulose (HEC), morpholinethanesulphonic acid (MES), sugars (fructose, glucose, sucrose, turanose, maltose, trehalose, melibiose) and organic acids (formic, tartaric, malic, succinic, citric, acetic, lactic, gluconic) were purchased from Merck KGaA (Germany). All chemicals were of analytical grade.

Sodium hydroxide [*pro analysis* (p.a.)], hydrochloric acid (35%), formaldehyde (36–38% aqueous solution), sodium carbonate (95%) and methanol [high-performance liquid chromatography (HPLC) grade] were purchased from Lach-Ner (Czech Republic).

Methods

Basic chemical parameters (assimilable nitrogen, ethanol, sugar-free extract). The assimilable nitrogen content was determined by formol titration (Aerny 1996). A DL22 automatic titrator (Mettler Toledo, Switzerland) with a DG115-SC combined glass electrode (Mettler Toledo, Switzerland) was used for titration. An aliquot of 0.1 mol L⁻¹ NaOH was used as a titrant.

The ethanol content was determined pycnometrically after distillation (OIV 2009). The mead was distilled using a Kjeldahl K-360 distillation unit (Büchi

Donaulab, Switzerland). The distillation time was 220 s and the unit performance level was at 70%.

The determination of the total extract was performed on the basis of pycnometric determination of the relative density of the sample and its distillate (OIV 2009). The sugar-free extract was calculated by subtracting the sugar content from the total extract.

5-Hydroxymethylfurfural (HMF) determination. The content of HMF was measured by HPLC according to the Harmonised Methods of the International Honey Commission (Bogdanov 2009). The samples were diluted 5-fold in 10% (v/v) methanol and filtered through a 0.45 µm membrane filter (Teknokroma Analytical S.A., Spain) to 1.5 mL vials. The analysis of HMF was performed using HPLC system (Agilent Technology 1290 series, USA) with a Hibar 125-4 Purospher STAR RP-18 (5 µm; Merck KGaA, Germany) and a diode-array detector (DAD) (Agilent Technology 1290 series, US). The conditions of the analysis were as follows – mobile phase: mixture of water and methanol [90 : 10 (v/v), isocratic conditions were used], flow rate 1 mL min⁻¹, temperature of the column 30 °C and the wavelength was adjusted at 285 nm. The external calibration curve produced using a standard solution was used to quantify the amount of HMF.

Determination of sugars by HPLC. The sugar profiling (fructose, glucose, sucrose, turanose, maltose, trehalose, and melibiose) was carried out by HPLC according to the Harmonised Methods of the International Honey Commission (Bogdanov 2009) with modifications. The samples were diluted 2-fold in distilled water and filtered through a 0.45 µm polytetrafluoroethylene (PTFE) syringe filter (Teknokroma Analytical S.A., Spain) into 1.5 mL vials. The analysis of sugars was determined using Dionex UltiMate 3000 [ultra-high performance liquid chromatography (UHPLC)] (Thermo Fisher Scientific, US) equipment with a Nucleosil 100-5 NH₂-RP column (Macherey-Nagel, Germany) and a Shodex RI-101 refractive index detector (Showa Denko K.K., Japan). The conditions of the analysis were as follows – mobile phase: mixture of water and acetonitrile [20 : 80 (v/v), isocratic conditions were used], flow rate 1 mL min⁻¹ and temperature of the column and detector 45 °C. The external calibration curves produced using standard solutions were used to quantify the amount of sugars.

Determination of acids by isotachopheresis. The acid content was determined using isotachopheresis (Farkaš and Kovaľ 1982). A capillary electrophoretic analyser (EA 101; Villa-Labeco, Slovakia) and the measurement conditions below were used: lead electrolyte 10 mM hydrochloric acid, 5.5 mM BTP, 0.1% HEC; ter-

minal electrolyte 5 mM MES; driving current (initial 70 µA, final 30 µA). A sample of the mead (1 mL) was diluted in a 50 mL volumetric flask with distilled water.

Total polyphenol content. The total polyphenol content was determined by the spectrophotometric method according to Folin-Ciocalteu (Singleton et al. 1998). Solution of Folin-Ciocalteu reagent (10%, 1 mL) was added to a mead sample (0.25 mL). After 3 min, 5 mL of Na₂CO₃ [7.5 g (100 mL)⁻¹] were added. This solution was left in the dark at room temperature (1 h) and then the absorbance (700 nm) was measured using the Minolta CM-5 spectrophotometer (Konica Minolta, Germany). The total polyphenol content was expressed as mg gallic acid equivalents per litre of mead (mg GAE L⁻¹).

Statistical analysis. All analyses were carried out in triplicate, and data were presented as the mean ± standard deviations (SD). Significant differences were verified by Student's *t*-test using Microsoft Excel 2016. In addition, the data were analysed using principal component analysis (PCA) using Statistica software 12.0 (Statsoft Inc., USA).

RESULTS AND DISCUSSION

Basic parameters of mead samples. The basic legislative parameters applicable to mead in the Czech Republic [Decree No. 248/2018 Coll. (Vyhláška č. 248/2018 Sb.)] include the content of ethanol and sugar-free extract. The minimum ethanol content [11% (v/v) for honey wines; 10% (v/v) for dessert mead] was met by all analysed samples, the average ethanol content of honey wines was 12.8% (v/v) (Table 1). Dessert mead was typically characterised by higher ethanol content [up to 17.9% (v/v)]. The detected concentrations of ethanol correspond to published studies, the most frequently reported content of ethanol in honey wines is in the range of 12.7–15.0% (v/v) (Ukpabi 2006; Vidrih and Hribar 2007). Two samples of honey wines (9H and 11H) did not meet the minimum sugar-free extract (20 g L⁻¹ for honey wines; not defined for dessert mead), while sample 7H (77.0 g L⁻¹) showed the highest amount of that. The content of sugar-free extract in honey wines depends on the amount of honey used; in the case of dessert mead, its content is affected by the addition of acids or colourings (Zoecklein et al. 1995).

The content of HMF in honey is one of the important quality parameters. There is no limit in the Czech legislation for the content of HMF in mead. However, if we start from the usual maximum limit defined for honey (40 mg kg⁻¹), then in the case of a traditional recipe (0.4 kg of honey per litre of mead) we should set the

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Table 1. Basic physico-chemical properties of honey wines and dessert mead [for comparison, the values defined by Czech legal regulations, i.e. Decree No. 248/2018 Coll. (Vyhlaška č. 248/2018 Sb.) are also included] ($n = 17$)

Physico-chemical parameter	Honey wine			Dessert mead		
	min.–max. range	mean $\pm$ SD	legislation ^d	min.–max. range	mean $\pm$ SD	legislation ^d
Sugar-free extract (g L ⁻¹) ^a	10.4–77.0	33.4 $\pm$ 17.9	min. 20	28.2–38.7	32.5 $\pm$ 4.2	nd
Ethanol [% (v/v)] ^b	11.4–14.5	12.8 $\pm$ 0.9	min. 11	12.5–17.9	15.4 $\pm$ 2.5	min. 10
Total sugar (g L ⁻¹) ^c	36.5–182.8	99.5 $\pm$ 36.9	nd	106.0–304.5	224.3 $\pm$ 69.3	min. 40
HMF (mg L ⁻¹) ^b	1.0–30.6	14.6 $\pm$ 9.3	nd	4.5–87.7	45.6 $\pm$ 32.6	nd
Assimilable nitrogen (mg L ⁻¹) ^a	23.9–316.1	88.0 $\pm$ 79.2	nd	9.1–123.6	55.5 $\pm$ 43.3	nd
Total polyphenol (mg GAE L ⁻¹) ^a	151.9–353.9	220.6 $\pm$ 56.1	nd	158.7–385.3	250.7 $\pm$ 84.8	nd

^aThere is no statistically significant difference between the groups ($P > 0.05$); ^bthere is a statistically significant difference between groups ($P \leq 0.05$); ^cthere is a statistically significant difference between groups ($P \leq 0.001$); ^dDecree No. 248/2018 Coll. (Vyhlaška č. 248/2018 Sb.); nd – not defined; SD – standard deviation; HMF – hydroxymethylfurfural; GAE – gallic acid equivalent

HMF content up to 16 mg L⁻¹. The main factor in this respect is the production technique itself. When heating is involved during the production, an increase in HMF content can be expected. In dessert mead, the HMF content increases due to the addition of sugars or colourings. The average HMF content of the analysed samples is given in Table 1. Samples of honey wines (on average 14.6 mg L⁻¹), which met the expected HMF limit, had the lowest HMF values. In contrast, most dessert meads showed a significantly increased HMF content (sample 12D to 87.7 mg L⁻¹). In a study by Kahoun et al. (2017), similar values for mead (3–158 mg L⁻¹) were recorded. The HMF content corresponds to the intensity of the heating of the honey solution, the quality of the honey and the storage conditions of the mead (Švecová et al. 2015; Kahoun et al. 2017). For a better comparison of the samples, it would be necessary to know the original HMF content of the honey and the storage conditions (time period, temperature) of the mead. Kahoun et al. (2017) also demonstrated that the use of a temperature of up to 80 °C for 60 min in the preparation of a honey solution will cause only a slight increase in the HMF content (10%). Higher temperatures will cause a more significant increase (90 °C: 36%, 100 °C: 93%). At the same time, storage at room temperature (in daylight) for 12 weeks was found to cause a 46% increase in HMF content (Kahoun et al. 2017).

Another parameter determined was the content of assimilable nitrogen (Table 1). Samples of dessert mead had a lower content of assimilable nitrogen (sample 17D, 10 mg L⁻¹), while honey wines were typically higher in their content (sample 5H, 316 mg L⁻¹). In mead made from honey only, the present pollen

(pollen contained in honey) is likely to affect the assimilable nitrogen content (Mendes-Ferreira et al. 2011; Roldán et al. 2011). During the production of mead, there is a significant dilution of honey and the content of assimilable nitrogen is therefore reduced. Thus, the final content of assimilable nitrogen in mead is likely to depend more on the nutrients added.

Comparison of phenolic compounds in mead.

The total polyphenol content depends on the type of honey used. Honeydew honeys contain a higher proportion of polyphenolic compounds (Švecová et al. 2015). The average polyphenol content of all samples was 231 mg GAE L⁻¹. Honey wines and dessert mead had a similar content of polyphenols (221 mg GAE L⁻¹ vs. 251 mg GAE L⁻¹) (Table 1). According to available studies, the total content of polyphenols in mead ranges from 116 mg GAE L⁻¹ to 240 mg GAE L⁻¹ (Wintersteen et al. 2005; Šmogrovičová et al. 2012).

Characteristic profile of sugars in mead samples.

During the fermentation of mead, the content of sugars is reduced, as they are converted into ethanol and carbon dioxide. In a study by Kim et al. (2005), the authors demonstrated that at the beginning of the fermentation of the honey solution (within 6 days) there is a significant decrease in reducing sugars. Subsequently, the content of reducing sugars remains constant for about 6 days and then it decreases again. The content of residual sugars significantly affects the taste and quality of mead, its value correlates with the sweet taste and the ethanol content of the final product (Sroka and Satora 2017).

The content of individual sugars of the analysed samples is given in Table 2. Honey wines showed large dif-

ferences in sugar content compared to dessert mead. The group of honey wines contained an average total sugar content of 99 g L⁻¹. In contrast, for dessert mead, the average total sugar content is 224 g L⁻¹ (sample 13D even 305 g L⁻¹) and the significant addition of sucrose (132 g L⁻¹) can be observed. According to the legislation, dessert mead must contain at least 40 g L⁻¹ of sugars [Decree No. 248/2018 Coll. (Výhláška č. 248/2018 Sb.)]. As argued by Švecová et al. (2015), less sweet mead should contain 40 g L⁻¹ to 100 g L⁻¹ of sugars and, conversely, very sweet mead may have up to 200 g L⁻¹. In a study by Juričová et al. (2018), the average sugar content in Czech mead is 97 g L⁻¹.

The profile of monosaccharides and disaccharides varied between samples significantly. The glucose content in honey wines ranged between 3 g L⁻¹ and 58 g L⁻¹, while the fructose content ranged between 17 g L⁻¹ and 104 g L⁻¹. Dessert mead was characterised by a higher proportion of monosaccharides compared to honey wines (i.e. glucose 33–113 g L⁻¹ and fructose 60–136 g L⁻¹). The highest content of glucose and fructose was found in dessert mead 13D, 14D, and 17D. The samples 13D and 17D were undoubtedly sweetened with beet sugar to improve the taste, which is confirmed by the high findings of sucrose (13D: 47 g L⁻¹, 17D: 77 g L⁻¹). In contrast, the lowest con-

tent of monosaccharides was recorded in honey wine samples 4H (24 g L⁻¹) and 7H (22 g L⁻¹). These samples can be classified as dry mead, and their low sugar content is probably due to the recipe used and the method of the fermentation process (a significant portion of the sugars was converted to ethanol).

In addition to the main monosaccharides, other minor disaccharides were identified in mead as well (Table 2). Turanose, maltose, and trehalose were detected in all samples of honey wines, while melibiose was found in only 40% of these samples. Honey wines contained a higher content of turanose (average 5.0 g L⁻¹), maltose (10.2 g L⁻¹), trehalose (4.1 g L⁻¹) as well as melibiose (1.5 g L⁻¹) compared to dessert mead. This fact is caused by the chosen recipe during production, i.e. mainly by the amount of honey used. In general, the presence of disaccharides in mead is explained by their poorer usability for the yeast present, because easily fermentable monosaccharides are preferred. In their study, Schwarz et al. (2020) cited the presence of rhamnose, trehalose, maltotetraose, maltotriose, melezitose, and melibiose as one of the main causes of high residual sugar concentrations. All these sugars have also been described in authentic honeys (da Silva et al. 2016). Other studies (da Silva et al. 2018) also attribute the residual concentration of sugars to the presence of treha-

Table 2. Sugar content in samples of honey wines and dessert mead (g L⁻¹) (mean ± SD; *n* = 17)

Sample No.	Fructose ^b	Glucose ^b	Sucrose ^a	Turanose ^c	Maltose ^a	Trehalose ^b	Melibiose ^a
1H	59.7 ± 3.0	35.4 ± 1.8	< 0.3	7.6 ± 0.4	14.8 ± 0.7	5.8 ± 0.3	< 0.3
2H	51.1 ± 2.6	18.9 ± 1.0	< 0.3	3.2 ± 0.2	5.1 ± 0.3	3.6 ± 0.2	< 0.3
3H	49.6 ± 2.5	34.8 ± 1.7	0.4 ± 0.0	4.7 ± 0.2	7.1 ± 0.4	4.0 ± 0.2	< 0.3
4H	17.3 ± 0.9	6.9 ± 0.4	< 0.3	4.0 ± 0.2	6.7 ± 0.3	1.5 ± 0.1	< 0.3
5H	31.5 ± 1.6	32.0 ± 1.6	< 0.3	7.0 ± 0.4	10.3 ± 0.5	3.5 ± 0.2	0.8 ± 0.0
6H	103.8 ± 5.2	57.8 ± 2.9	< 0.3	5.0 ± 0.3	8.4 ± 0.4	6.7 ± 0.3	1.1 ± 0.1
7H	19.4 ± 1.0	2.5 ± 0.1	< 0.3	7.2 ± 0.4	22.8 ± 1.1	10.1 ± 0.5	2.8 ± 0.1
8H	50.0 ± 2.5	16.7 ± 0.8	< 0.3	5.6 ± 0.3	13.8 ± 0.7	6.6 ± 0.3	1.4 ± 0.1
9H	78.5 ± 3.9	35.3 ± 1.8	< 0.3	3.8 ± 0.2	8.7 ± 0.4	1.4 ± 0.1	< 0.3
10H	72.5 ± 3.6	36.9 ± 1.9	< 0.3	3.1 ± 0.2	7.1 ± 0.4	1.1 ± 0.1	< 0.3
11H	48.2 ± 2.4	10.3 ± 0.5	6.7 ± 0.3	3.7 ± 0.2	7.4 ± 0.4	1.2 ± 0.1	< 0.3
12D	91.0 ± 4.6	80.6 ± 4.0	< 0.3	2.0 ± 0.1	5.0 ± 0.3	0.6 ± 0.0	< 0.3
13D	131.8 ± 6.6	113.1 ± 5.7	46.8 ± 2.3	< 0.3	12.9 ± 0.6	< 0.3	< 0.3
14D	136.3 ± 6.8	106.9 ± 5.3	0.4 ± 0.0	0.4 ± 0.0	0.5 ± 0.1	< 0.3	< 0.3
15D	59.6 ± 3.0	32.9 ± 1.6	< 0.3	3.3 ± 0.2	8.2 ± 0.4	2.0 ± 0.1	< 0.3
16D	118.2 ± 5.9	91.3 ± 4.6	0.9 ± 0.1	0.3 ± 0.0	1.1 ± 0.1	< 0.3	< 0.3
17D	122.2 ± 6.1	101.4 ± 5.1	76.5 ± 3.8	< 0.3	< 0.3	< 0.3	< 0.3

^aThere is no statistically significant difference between the groups (*P* > 0.05); ^bthere is a statistically significant difference between groups (*P* ≤ 0.05); ^cthere is a statistically significant difference between groups (*P* ≤ 0.001); SD – standard deviation; H – honey wine; D – dessert mead

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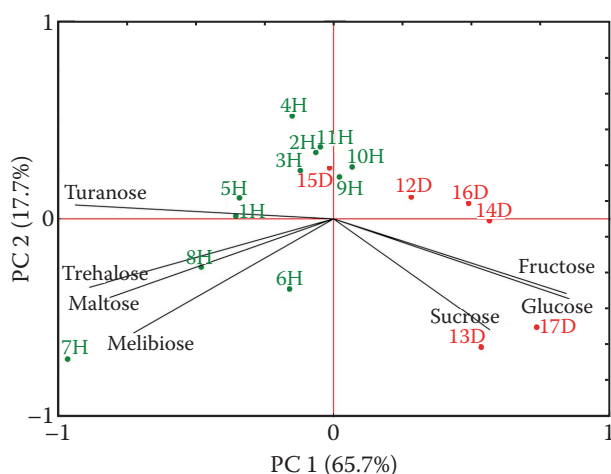


Figure 1. Principal component analysis (PCA) of the effect of specified sugars (biplot; $n = 17$)

H – honey wines; D – dessert mead; PC 1, PC 2 – 1st and 2nd principal components, respectively

lose, isomaltose, and melezitose. The statistical method of PCA was used for the overall evaluation of the sugar profile. The values of the first two main components and their relation to the original features are shown in Figure 1. The diagram clearly illustrates that the sugar profile reliably divides the samples into two expected groups. Honey wines are expressed by negative values

of the first main component, while dessert meads show their positive values. Furthermore, the effect of individual sugars is obvious. Honey wines are characterised mainly by the content of turanose and trehalose, while for dessert mead the content of fructose, glucose, and sucrose is significant.

Differences in the content of organic acids in mead.

The content of organic acids varied considerably between individual samples of mead (from 0.01 g L⁻¹ of succinic acid up to 4.50 g L⁻¹ of lactic acid) (Table 3). The literature shows that gluconic acid is the most abundant in honey. However, its content is highly dependent on botanical and geographical origin. The published studies (Tezcan et al. 2011; Daniele et al. 2012) report gluconic acid concentrations for chestnut (11.2–12.7 g kg⁻¹) and black locust honeys (1.5–1.8 g kg⁻¹). The proportion of other organic acids in honey is also very variable, e.g. formic acid (0.01–1.90 g kg⁻¹), citric acid (0.04–0.47 g kg⁻¹) or succinic acid (0.02–0.23 g kg⁻¹) (Suárez-Luque et al. 2002; Tezcan et al. 2011; Daniele et al. 2012).

Table 3 clearly shows that gluconic acid is not a dominant acid in the analysed samples. Concentrations of this acid ranged from 0.1 g L⁻¹ to 1.7 g L⁻¹. The lowest content was found in sample 17D (dessert mead), while the highest content was found in sample 1H (honey wine). The gluconic acid content is probably re-

Table 3. Content of organic acids in samples of honey wines and dessert mead (g L⁻¹) (mean $\pm$ SD; $n = 17$)

Sample No.	Formic acid ^a	Tartaric acid ^a	Malic acid ^a	Succinic acid ^b	Citric acid ^a	Acetic acid ^a	Lactic acid ^a	Gluconic acid ^a
1H	0.58 $\pm$ 0.00	0.07 $\pm$ 0.01	0.10 $\pm$ 0.00	0.06 $\pm$ 0.00	0.89 $\pm$ 0.01	0.60 $\pm$ 0.00	0.26 $\pm$ 0.00	1.68 $\pm$ 0.01
2H	0.23 $\pm$ 0.01	0.07 $\pm$ 0.01	0.28 $\pm$ 0.01	0.76 $\pm$ 0.05	0.13 $\pm$ 0.04	0.46 $\pm$ 0.01	0.19 $\pm$ 0.00	0.44 $\pm$ 0.03
3H	0.35 $\pm$ 0.00	< 0.01	0.12 $\pm$ 0.00	0.18 $\pm$ 0.02	0.34 $\pm$ 0.00	< 0.01	4.50 $\pm$ 0.06	0.45 $\pm$ 0.02
4H	0.15 $\pm$ 0.00	0.51 $\pm$ 0.01	0.62 $\pm$ 0.01	0.45 $\pm$ 0.01	0.23 $\pm$ 0.02	0.03 $\pm$ 0.00	1.05 $\pm$ 0.04	0.58 $\pm$ 0.06
5H	1.06 $\pm$ 0.01	< 0.01	0.16 $\pm$ 0.00	0.15 $\pm$ 0.02	0.23 $\pm$ 0.01	0.19 $\pm$ 0.01	1.26 $\pm$ 0.04	0.47 $\pm$ 0.02
6H	0.14 $\pm$ 0.01	0.04 $\pm$ 0.01	0.15 $\pm$ 0.00	0.22 $\pm$ 0.00	0.23 $\pm$ 0.03	0.06 $\pm$ 0.01	1.09 $\pm$ 0.03	0.61 $\pm$ 0.05
7H	0.28 $\pm$ 0.00	< 0.01	0.14 $\pm$ 0.01	0.01 $\pm$ 0.02	0.37 $\pm$ 0.03	0.18 $\pm$ 0.00	0.81 $\pm$ 0.11	0.99 $\pm$ 0.03
8H	0.09 $\pm$ 0.01	0.11 $\pm$ 0.02	0.14 $\pm$ 0.00	< 0.01	0.45 $\pm$ 0.01	0.26 $\pm$ 0.00	1.24 $\pm$ 0.00	0.47 $\pm$ 0.03
9H	0.11 $\pm$ 0.00	0.07 $\pm$ 0.01	0.07 $\pm$ 0.00	0.29 $\pm$ 0.00	0.13 $\pm$ 0.00	0.74 $\pm$ 0.00	0.19 $\pm$ 0.00	0.43 $\pm$ 0.02
10H	0.13 $\pm$ 0.00	0.30 $\pm$ 0.00	0.24 $\pm$ 0.00	0.34 $\pm$ 0.00	0.17 $\pm$ 0.00	0.65 $\pm$ 0.00	0.31 $\pm$ 0.00	0.34 $\pm$ 0.01
11H	0.11 $\pm$ 0.00	0.49 $\pm$ 0.03	< 0.01	0.24 $\pm$ 0.00	0.16 $\pm$ 0.00	0.96 $\pm$ 0.01	0.48 $\pm$ 0.01	0.97 $\pm$ 0.01
12D	0.28 $\pm$ 0.02	0.49 $\pm$ 0.03	0.19 $\pm$ 0.07	0.22 $\pm$ 0.00	0.12 $\pm$ 0.00	1.55 $\pm$ 0.01	1.82 $\pm$ 0.00	0.50 $\pm$ 0.00
13D	0.07 $\pm$ 0.00	< 0.01	0.11 $\pm$ 0.00	< 0.01	1.05 $\pm$ 0.01	0.37 $\pm$ 0.00	0.11 $\pm$ 0.00	0.13 $\pm$ 0.00
14D	0.11 $\pm$ 0.01	< 0.01	0.25 $\pm$ 0.02	0.08 $\pm$ 0.00	0.28 $\pm$ 0.00	0.10 $\pm$ 0.00	1.32 $\pm$ 0.02	0.44 $\pm$ 0.01
15D	0.16 $\pm$ 0.00	< 0.01	0.10 $\pm$ 0.02	0.15 $\pm$ 0.01	0.05 $\pm$ 0.01	0.43 $\pm$ 0.03	1.64 $\pm$ 0.01	0.66 $\pm$ 0.06
16D	0.34 $\pm$ 0.00	< 0.01	0.08 $\pm$ 0.03	< 0.01	0.71 $\pm$ 0.01	0.06 $\pm$ 0.00	0.87 $\pm$ 0.03	0.29 $\pm$ 0.02
17D	0.09 $\pm$ 0.00	< 0.01	0.12 $\pm$ 0.01	< 0.01	1.10 $\pm$ 0.01	0.35 $\pm$ 0.00	0.16 $\pm$ 0.01	0.12 $\pm$ 0.00

^aThere is no statistically significant difference between the groups ($P > 0.05$); ^bthere is a statistically significant difference between the groups ($P \leq 0.05$); SD – standard deviation; H – honey wine; D – dessert mead

lated to the amount of honey used, as higher gluconic acid content was measured in honey wines (average 0.7 g L^{-1}) than in dessert mead (average 0.4 g L^{-1}). This hypothesis is also confirmed by values from the study by Dobrowolska-Iwanek (2015), who found a gluconic acid concentration in the mead of 1.1 g L^{-1} (honey to water ratio 1 : 2) and 0.5 g L^{-1} (honey to water ratio 1 : 3). On the contrary, the obtained values are in conflict with the study by Švecová et al. (2015), where the authors reported many times higher concentrations of this acid (approximately 29 g L^{-1}).

Furthermore, lactic acid (average 1.0 g L^{-1}) and acetic acid (0.4 g L^{-1}) were present in significant amounts in the analysed mead. The significant proportion of acetic acid was also confirmed by Sroka and Tuszyński (2007), who found that during the first 14 days of fermentation of honey solution there is a significant increase in acetic acid and succinic acid, while formic acid was found to decrease. The analysed honey wines were typically higher in succinic acid (average 0.3 g L^{-1}), while dessert mead had a lower content of this acid (average 0.1 g L^{-1}). So it is clear that the succinic acid content is probably related to the amount (type) of honey used.

Citric acid is another important acid in mead. Citric, malic or tartaric acids are often used to adjust the pH of a honey solution (Pereira et al. 2017). During fermentation, there are no significant changes in the citric acid content (Sroka and Tuszyński 2007). The content of citric acid was significantly variable between individual samples ($0.1\text{--}1.1 \text{ g L}^{-1}$) (Table 3). For sample 1H (honey wine), the manufacturer does not declare the addition of citric acid, but its content was the highest in this group of samples (0.9 g L^{-1}). The value found indicates that citric acid was added during production. For samples 13D, 16D, and 17D (dessert mead), the manufacturer declared the addition of citric acid, and it was determined to be in the range of $0.7\text{--}1.1 \text{ g L}^{-1}$. According to literature sources, the content of citric acid in Czech mead reaches $0.1\text{--}3.1 \text{ g L}^{-1}$ (Švecová et al. 2015).

The ability of the organic acid profile to characterise the type of mead was assessed using PCA. The PCA results for the analysed sample set are shown in Figure 2. The first main component (totalling 30% of the data variability) is most closely linked to citric, succinic, and tartaric acid. In contrast, the second major component (containing 19% of the data variability) is represented by acetic, gluconic, and lactic acid content. The diagram shows that the profile of organic acids does not contribute to the separation of two groups of samples. It can be expected that the profile of organic acids

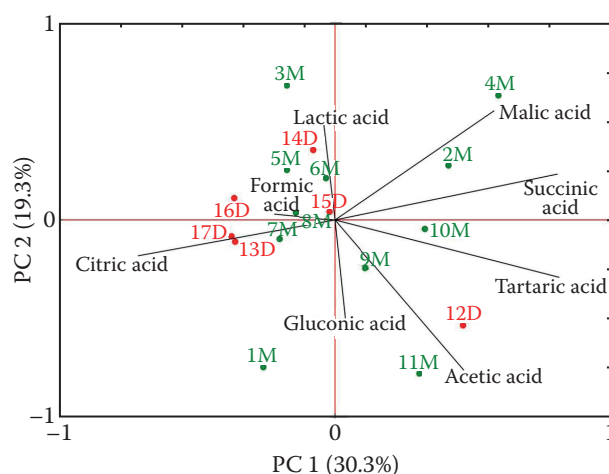


Figure 2. Principal component analysis (PCA) of the effect of the acids present (biplot; $n = 17$)

H – honey wines; D – dessert mead; PC 1, PC 2 – 1st and 2nd principal components, respectively

is mainly influenced by honey (the main raw material for production) and by the fermentation process.

CONCLUSION

The study was focused on the evaluation of selected qualitative features of honey wines and dessert meads from various producers from the Czech Republic. Analysed two groups of samples (honey wines *vs.* dessert mead) were statistically significantly different in the following parameters (average values): ethanol content [12.8% *vs.* 15.4% (v/v)], sugar content (99.5 g L^{-1} *vs.* 224.3 g L^{-1}), HMF (14.6 mg L^{-1} *vs.* 45.6 mg L^{-1}), fructose (52.9 g L^{-1} *vs.* 109.9 g L^{-1}), glucose (26.1 g L^{-1} *vs.* 87.7 g L^{-1}), turanose (5.0 g L^{-1} *vs.* 1.5 g L^{-1}), trehalose (4.1 g L^{-1} *vs.* 1.3 g L^{-1}), and succinic acid (0.3 g L^{-1} *vs.* 0.2 g L^{-1}). The results suggest that the content of minor sugars in particular depends on the amount and type of honey to a large extent. The HMF content also proved to be a useful parameter for the evaluation of the heat treatment of mead. This study is the first work to distinguish between traditional mead (honey wines) and dessert meads. The presented results also provide valuable information for a potential quality assessment.

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