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Article

Quality Characterization of Honeys from Iraqi Kurdistan

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Abstract: The aim of this study was to research the quality parameters of honeys directly from Iraqi Kurdistan beekeepers and to compare with European Union law and Central European honeys. In total 30 honey samples directly from Kurdish, Czech and Slovak beekeepers were collected from the year of production 2018. The analyzed physicochemical parameters and bioactive compounds (moisture content, electrical conductivity, diastase activity, hydroxymethylfurfural content, pH, free acidity, total phenolic content, color, color intensity) varied depending on the botanical and geographical origin of honeys. Comparing Kurdistan honeys with a directive relating to honey, only two honey samples had diastase activity lower than limit and one sample had free acidity value at the legislative limit. Based on the results, it was found that the properties of Kurdistan honeys were very similar to the properties of Czech and Slovak honeys, as indicated by the detected statistically non-significant differences ($p > 0.05$) between the moisture content, electrical conductivity, diastase activity and color. On the contrary, the most significant differences ($p < 0.01$) were detected in hydroxymethylfurfural content, total phenolic content, and color intensity. Our results indicated the specific properties and the uniqueness of honeys from Iraqi Kurdistan and pointed to the possibility of trading this honey in Europe.

Keywords: physicochemical properties; hydroxymethylfurfural; color intensity; phenolic content; diastase activity

1. Introduction

In Europe, beekeeping and honey production are a common part of agriculture, also in view of the appropriate climatic, environmental, and economic conditions. According to Al-Badri [1] the honey production in Iraq is influenced by environmental issues like little rain, desertification, using of pesticides, and economical problems. Iraq is climatically diverse, with continental, subtropical semi-arid type, and Mediterranean climate in the north and north-eastern region. Rainfall is very seasonal. Summers in Iraq are characterized by drought, hot to extremely hot, with temperatures of over 43 degrees of Celsius during July and August [2]. The environment of Kurdistan is very diverse and consists of areas of forests and mountains herbs (mainly with oaks, almonds, walnuts, pines, pistachios, grasses, and shrubs), plains regions (with grasses, bulbous, thorny, and spiny plants), and areas of riverbanks (with willows, shrubs, grasses, liquorice, and thorny plants). This diverse flora provides pasture for the bees. In 2008, 3 258 beekeepers were recorded in Dohuk Governorate of Iraqi Kurdistan, which is the second highest number after Sulaimania Governorate. Total annual production of honey in Iraqi Kurdistan ranges from 600 to 800 tons [3].

To date, no works related to the analysis of honey from the Dohuk Governorate of Iraqi Kurdistan have been published and a narrow range of work has been published about the analysis of honeys originating from Kurdistan province of Iran [4–6]. Some works are focused specifically on the biological activity of Iraqi honey and little data have been published on the physicochemical properties. Ali et al. [7] identified by GC-MS method in Iraqi honeys wide range of volatile

compounds like alcohols, phenols, ketones, organic acids, and esters with antibacterial, antifungal, and anticancer activity. Hamed et al. [8] focused to determination of water-soluble vitamins of B-complex group in Iraqi honeys by HPLC method. Al-Hasani et al. [9] detected antibacterial effect of Iraqi honey samples against gram-positive and gram-negative bacteria at concentration of 100 % and the inhibition effect of honey decreased as honey diluted. Abu-Almaaly [10] focused on identification of some heavy metals in samples of Iraqi honeys by atomic absorption technique. The same author detected cadmium, lead, nickel and iron in honey samples and concentrations of these heavy metals varied according to the areas of honey collection.

The chemical composition of honey is variable depending on the floral source and geographical origin. Honey is a mixture of different components such as carbohydrates, water, proteins, amino acids, enzymes, vitamins, phenolic acids, minerals, volatile compounds, pigments, and other substances [11].

The moisture content in honey usually ranges from 15% to 21 %. The moisture content of honey is important for honey stability, and the low moisture content avoids the honey fermentation [12]. The hydroxymethylfurfural (HMF) content and diastase activity reflect the freshness and heat treatment of the honey. Shortly after extraction, the honey has a low HMF content and relatively high diastase activity, depending on the origin of the honey. Subsequently, because of various technological steps such as heating and long-term storage, concentration of HMF is increasing, and diastase activity decreases [13]. Honey's phenolic compounds are secondary plant metabolites represented by flavonoids and phenolic acids [14], originating from flower nectar, propolis and pollen [15]. The total phenolic content indicates the content of phenolic substances that are important from a nutritional point of view due to their antiviral, antimicrobial, antioxidant, anti-inflammatory, anti-atherogenic, and anticancer properties [11,15].

The chemical composition of honey affects the physicochemical properties of honey such as electrical conductivity, color, and pH. The electrical conductivity of honey correlates with the content of mineral substances in honey, which ranges from 0.04% to 0.2% [11]. Due to higher mineral content, honeydew honeys usually have higher electrical conductivity, in comparison with nectar honeys [16]. Color properties such as honey color and color intensity are variable depending on the content of different coloring substances, such as phenolic acids, flavonoids, carotenoids, Maillard reaction products, mineral substances, and pollen grains [17,18]. The pH value reflects acid content of honey and indicate honey fermentation. Honey naturally contains numerous organic and inorganic acids and pH value of honey varies from 3.4 to 6.2, depending on botanical origin of honey [13].

In the European Union is the quality of honey regulated by Council Directive of the EU 110/2001 [19] related to honey. This EU legal act specifies composition criteria for saccharide content, hydroxymethylfurfural content, moisture content, electrical conductivity, free acidity, diastase activity, and water-insoluble content in honeys. In Kurdistan, there are no standard specifications for evaluating the quality of produced honey, and there are no specialized laboratories [3].

Due to the scarcity of published data that comprehensively evaluates the properties of honeys directly from Kurdish beekeepers from Iraqi Kurdistan, the main objectives were to (1) analyze specific physicochemical and bioactive parameters relating to honey quality and biological value in honeys collected directly from Kurdish beekeepers from Dohuk and Erbil Governorates of Iraqi Kurdistan, and (2) to compare the quality of Kurdistan honeys with the requirements of European Union law and (3) to compare the parameters of Kurdistan honeys with honeys directly from Czech and Slovak beekeepers.

2. Materials and Methods

2.1. Honey Samples from Kurdish Beekeepers

Ten honey samples were obtained directly from Kurdish beekeepers from Iraqi Kurdistan. Honey samples were produced in different areas of the Dohuk and Erbil Governorates in 2018. Eight samples of honey came from beekeeping and two samples from wild bees. All honey samples were nectar honeys. The samples were stored in the dark at room temperature (21 ± 2 °C) in original

packaging from beekeepers until the analysis. A detailed specification of the analyzed honey samples from Kurdish beekeepers is given in the Table 1.

Table 1. Additional information on honey samples from Iraqi Kurdistan.

Honey Sample	Area	Origin
KH1	Dohuk Governorate (city)	beekeeping
KH2	Dohuk Governorate (city)	beekeeping
KH3	Šejk Hassan - Dohuk Governorate	beekeeping
KH4	Sydky - Dohuk Governorate	beekeeping
KH5	Akre - Dohuk Governorate	beekeeping
KH6	Brifka - Dohuk Governorate	beekeeping
KH7	Barbir - Dohuk Governorate	wild
KH8	Bstana - South of the city Erbil- Erbil Governorate	beekeeping
KH9	Atrush - Dohuk Governorate	beekeeping
KH10	Karah - Dohuk Governorate	wild

2.2. Honey Samples from Czech and Slovak Beekeepers

Totally twenty honey samples of different botanical and geographical origin were collected directly from Czech (n = 10) and Slovak beekeepers (n = 10). Honeys were produced in various regions of Czech (Vlkaneč (n = 3); Lupůvka (n = 1); Valtice (n=1); Brno (n = 5)) and Slovak Republic (Borský Mikuláš (n = 1); Hradište pod Vrátnom (n = 1); Podbranč (n = 2), Senica, Kunov (n = 4); Lehota (n = 1); Piešťany (n = 1)) in 2018. All honey samples were nectar honeys. The samples were stored in the dark at room temperature (21 ± 2 °C) in their original packaging until the analysis.

2.3. Legislative Composition Criteria and pH

All standards and chemicals used in this study were of analytical grade. Diastase activity, hydroxymethylfurfural content, moisture content, electrical conductivity, pH, and free acidity were determined according to the Harmonized Methods of the International Honey Commission [20].

Diastase activity in honey samples was determined spectrophotometrically based on the Phadebas method (Phadebas Honey Diastase Test, Phadebas AB, Kristianstad, Sweden) using Specord 200 Plus spectrophotometer (Analytic Jena AG, Jena, Germany) at 620 nm. The diastase activity was expressed as the diastase number (DN) in Schade units.

Hydroxymethylfurfural content in honey samples was analyzed using the HPLC-UV method. The analysis was performed using an HPLC system (Alliance 2695, PDA detector 2996, Waters, Milford, Massachusetts, USA), a column (Zorbax Eclipse XDB-C18-5 μm, Agilent, Santa Clara, California, USA), with water-methanol (90:10) mobile phase. The analysis conditions were as follows: isocratic elution, flow rate 1.0 mL/min, sample injection 20 μL and column temperature 35 °C. HMF was detected and quantified in the UV at 285 nm using external standard and expressed in mg/kg of honey.

Moisture content in honey samples were determined using the refractometric method with the Abbé refractometer (AR 4, A.Krüss Optronic GmbH, Hamburg, Germany). Moisture content was expressed in g/100 g after the conversion of determined refractive index.

Electrical conductivity was determined using the conductometric method on an inoLab Cond 730 conductometer (WTW, Weilheim, Germany). Electrical conductivities were expressed in milli Siemens per meter (mS/m).

pH and free acidity were determined using pH meter MP230 (Mettler-Toledo, Greifensee, Switzerland) and an HC 113 electrode (Theta 90, Prague, Czech Republic). Three-point calibration was used at pH 4.0, 7.0 and 10.0. The honey samples were dissolved in distilled water without carbon dioxide and titrated with 0.1 mol/L sodium hydroxide (Penta, Czech Republic) solution to pH 8.3. Free acidity of honey was expressed in milliequivalents per kg of honey.

2.4. Bioactive Compounds

The total phenolic contents were determined by the Folin-Ciocalteu method described by Silici et al. [21]. The absorbance was measured at 765 nm using a Specord 200 Plus spectrophotometer (Analytic Jena AG, Jena, Germany). Standard calibration solutions were diluted from a gallic acid (Penta, Czech Republic) stock solution at a concentration range of 0–900 mg/10 mL ($R^2 = 0.9990$). The results were expressed as mg of gallic acid equivalent (GAE) per 100 g of honey.

Honey color intensity was analyzed according to the method described by Beretta et al. [17]. The absorbance was measured at two different wavelengths (450 nm and 720 nm) using Specord 200 Plus spectrophotometer (Analytic Jena AG, Jena, Germany) and the difference in absorbance was expressed as mAU.

The color of the honey samples was measured using Honey Color Photometer Hanna HI96785 (Hanna Instruments, Jud. Salaj, Romania). Colorimeter was calibrated with glycerol standard reference (Hanna Instruments, Jud. Salaj, Romania) and honey color was expressed in millimeter (mm) Pfund. The analyzed honey samples were categorized using the United States Department of Agriculture (USDA) approved color standards [22].

2.5. Statistical Analysis

All assays were performed in duplicate, and the results were expressed as a mean value $\pm$ standard deviation (SD). The statistical analysis of the results was performed with the Unistat (6.5) software and the Microsoft Excel 2016. The significant differences were obtained by a Shapiro-Wilk Normality Test followed by Mann-Whitney U Test. The differences at a 95 % ($p < 0.05$) confidence level were considered statistically significant.

3. Results and Discussion

3.1. Legislative Composition Criteria and pH

3.1.1. Moisture Content

The moisture content of Kurdistan honeys ranged from 15.0 ± 0.1 g/100 g to 17.5 ± 0.1 g/100 g. All analyzed Kurdistan honey samples did not exceed the established limit for moisture content (not more than 20 g/100 g) according to the Council Directive of the EU 110/2001 [19]. All measured moisture contents in Kurdistan honeys are summarized in Table 2. The average moisture content (g/100 g) of the analyzed Kurdistan honeys (16.2 ± 0.9) was comparable to the moisture contents of the analyzed Czech (16.3 ± 0.7) and Slovak honeys (16.4 ± 0.7). Non-significant difference ($p > 0.05$) between moisture contents of the Kurdistan honeys and Czech and Slovak honeys was observed. All determined statistical differences between each group of analyzed honeys are summarized in Table 3.

Table 2. Physicochemical parameters of the analyzed Kurdistan honeys.

Samples	Moisture (g/100 g)	Conductivity (mS/m)	Diastase (DN)	HMF (mg/kg)	Free acidity (meq/kg)	pH
KH1	15.5 $\pm$ 0.4	31.4 $\pm$ 2.1	19.6 $\pm$ 0.0	8.4 $\pm$ 0.1	36.5 $\pm$ 1.2	3.5 $\pm$ 0.0
KH2	16.9 $\pm$ 0.1	32.3 $\pm$ 1.2	4.7 $\pm$ 0.2	15.2 $\pm$ 0.4	37.0 $\pm$ 1.0	3.5 $\pm$ 0.0
KH3	16.1 $\pm$ 0.0	33.9 $\pm$ 1.7	13.9 $\pm$ 0.7	13.4 $\pm$ 2.0	28.0 $\pm$ 1.3	3.7 $\pm$ 0.0
KH4	15.3 $\pm$ 0.2	34.4 $\pm$ 3.4	19.9 $\pm$ 0.5	15.2 $\pm$ 1.7	33.0 $\pm$ 0.5	3.9 $\pm$ 0.0
KH5	15.8 $\pm$ 0.0	49.8 $\pm$ 0.9	21.7 $\pm$ 1.3	11.0 $\pm$ 1.0	49.5 $\pm$ 1.2	3.9 $\pm$ 0.0
KH6	16.2 $\pm$ 0.0	29.8 $\pm$ 1.4	23.4 $\pm$ 1.5	11.5 $\pm$ 0.3	41.5 $\pm$ 0.8	3.7 $\pm$ 0.0
KH7	17.4 $\pm$ 0.1	22.2 $\pm$ 0.6	12.7 $\pm$ 0.4	8.4 $\pm$ 1.2	30.0 $\pm$ 1.0	3.5 $\pm$ 0.0
KH8	15.0 $\pm$ 0.1	27.3 $\pm$ 3.5	6.0 $\pm$ 0.4	11.0 $\pm$ 1.5	21.0 $\pm$ 0.7	3.6 $\pm$ 0.0
KH9	17.5 $\pm$ 0.1	31.7 $\pm$ 0.0	11.7 $\pm$ 0.2	5.0 $\pm$ 0.4	32.0 $\pm$ 0.2	3.9 $\pm$ 0.0
KH10	16.6 $\pm$ 0.2	24.2 $\pm$ 0.5	19.1 $\pm$ 0.3	5.0 $\pm$ 0.1	26.0 $\pm$ 1.8	3.7 $\pm$ 0.0
Min.	15.0	22.2	4.7	5.0	21.0	3.5

Max.	17.5	49.8	23.4	15.2	49.5	3.9
Median	16.2	31.5	16.5	11.0	32.5	3.7

HMF – hydroxymethylfurfural.

Table 3. Comparison of Kurdistan and Czech and Slovak honeys.

	Kurdistan (n = 10)	Czech (n = 10)	Slovak (n = 10)	Czech and Slovak (n = 20)
Moisture (g/100 g)	16.2 ± 0.9a	16.3 ± 0.7a	16.4 ± 0.7a	16.3 ± 0.8a
Conductivity (mS/m)	31.7 ± 7.5a	37.2 ± 21.5a	33.7 ± 19.1a	34.5 ± 19.9a
Diastase (DN)	15.3 ± 6.5a	14.6 ± 3.3a	14.4 ± 4.2a	14.5 ± 3.6a
HMF (mg/kg)	10.4 ± 3.7a	6.5 ± 5.1a	3.8 ± 2.1b**	5.1 ± 4.0b**
TPC (mg GAE/100 g)	56.9 ± 14.6a	40.9 ± 13.6b	34.0 ± 11.4b**	37.4 ± 12.7b**
Color (mm Pfund)	36.7 ± 20.6a	54.8 ± 28.3a	39.4 ± 21.3a	47.1 ± 25.6a
Color int. (mAU)	323 ± 151a	101 ± 72b**	72 ± 44b**	86 ± 60b**

ab – different letters indicate a statistically significant difference, (**) most significant difference (p < 0.01), (*) significant difference (p < 0.05), HMF – hydroxymethylfurfural, TPC – total phenolic content.

In contrast with our results, Khanbabaie et al. [5] determined lower average moisture content (13.79 g/100 g) in honeys from Kurdistan province of Iran. As well as Emamifar and Hosseinpanahi [6] determined lower average moisture contents in Kurdistan honeys from Saghez (13.96 g/100 g) and Sanandaj (14.42 g/100 g) regions. Lower moisture content (13.85 ± 3.75 g/100 g) also detected Parviz et al. [4] in Kurdistan province of Iran. Abdulkhaliq and Swaileh [23] detected very similar moisture content (16.53 ± 0.00 g/100 g) in honeys from West Bank, Palestine. Despite the different climatic and geographic conditions, the moisture content of Kurdistan honeys was very similar to Czech and Slovak honeys and more, the requirements of European Union law were fully met. Some differences pointed to the effect of season and geographic conditions on the moisture content of honey.

3.1.2. Electrical Conductivity

The electrical conductivity of Kurdistan honeys ranged from 22.2 ± 0.6 mS/m to 49.8 ± 0.9 mS/m. According to the Council Directive of the EU 110/2001 [19], all honey samples analyzed in this study were classified as nectar honeys (electrical conductivity not more than 80 mS/m). Kurdistan honey samples with the two lowest values of electrical conductivity came from wild bees from Barbir and Karah area. Similar results of electrical conductivity determined Emamifar and Hosseinpanahi [6] in Saghez honeys (36 mS/m) and Sanandaj honeys (22 mS/m) from Kurdistan province of Iran. Electrical conductivities of all analyzed honeys were similar and non-significant difference (p > 0.05) between electrical conductivities of the Kurdistan honeys and Czech and Slovak honeys was observed. The lower electrical conductivity values determined in honey from wild bees reflected specific and different nectar sources of these bees.

3.1.3. Diastase Activity

The diastase activity of Kurdistan honeys was variable parameter ranging from 4.7 ± 0.2 DN to 23.4 ± 1.5 DN. Among the analyzed Kurdistan honeys diastase activity lower than limit (not less than 8 Schade scale) according to the Council Directive of the EU 110/2001 [19] was detected in 2 honey samples (KH2 and KH8), specifically from Dohuk city and Bstana. Low diastase activities pointed to the specific properties of these honeys, while European Union law also established an exception for diastase activity for honeys with low natural enzyme content, for example citrus honeys. The diastase activities of the analyzed Kurdistan honeys were similar to the diastase activities of the analyzed Czech and Slovak honeys. Overall, non-significant difference (p > 0.05) between diastase activities of the Kurdistan honeys and Czech and Slovak honeys was observed. All measured diastase activities in Kurdistan honeys are summarized in Table 2.

Emamifar and Hosseinpanahi [6] reported similar diastase activities in Saghez honeys (11.3 DN) and Sanandaj honeys (15.26 DN) from Kurdistan province of Iran. Lower diastase activities also under the limit (not less than 8 DN) from 1.00 DN to 15.95 DN detected Afshari et al. [24] in honey samples from Khorasan province of Iran. In contrast, Parviz et al. [4] detected in honeys from Kurdistan province of Iran higher average diastase activity (29.7 ± 0.92 DN). Despite the different - warmer climate of Kurdistan honey production, diastase activities of Kurdistan honeys and European honeys were very similar, and different results in comparison with other authors pointed to the variability of this parameter depending on the botanical and geographical origin of honey.

3.1.4. Hydroxymethylfurfural Content

According to the Council Directive of the EU 110/2001 [19] honey should not contain more than 40 mg per kg of the HMF. The HMF contents of all tested honey samples from Kurdistan beekeepers did not exceed the established limit. The HMF contents (mg/kg) of honeys from Kurdistan beekeepers ranged from 5.0 ± 0.1 to 15.2 ± 1.7 ; with the average HMF concentration 10.4 ± 3.7 . In comparison with HMF contents of Czech and Slovak honeys, the most significant difference ($p < 0.01$) was observed. Higher determined HMF contents in Kurdistan honeys could point to different climatic conditions in Iraqi Kurdistan.

In great agreement with our results, Emamifar and Hosseinpanahi [6] determined similar HMF contents in Saghez honeys (9.26 mg/kg) and Sanandaj honeys (5.63 mg/kg) from Kurdistan province of Iran. In contrast, Parviz et al. [4] detected in honeys from Kurdistan province of Iran several times lower average HMF content (0.92 ± 0.38 mg/kg). On the other hand, Afshari et al. [24] and Abdulkhalik and Swaileh [23] detected in honey samples from Khorasan province of Iran and honeys from Palestine higher HMF content even above 30 mg/kg. Concentration of HMF is very variable parameter of honey. Variation of our results in comparison with other authors indicated variability of this parameter depending on several factors like climatic conditions, impact of honey processing or handling on honey quality.

3.1.5. Free Acidity and pH

According to the Council Directive of the EU 110/2001 [19] honey should not contain more than 50 milli-equivalents acid per kg. Free acidity (meq/kg) of Kurdistan honeys ranged from 21.0 ± 0.7 to 49.5 ± 1.2 . All tested honey samples from Kurdistan beekeepers did not exceed the established limit for free acidity, except for one value at the limit (49.5 ± 1.2 meq/kg). Despite the detected value at the limit, none of the tested samples showed signs of fermentation. Parviz et al. [4] detected in honeys from Kurdistan province of Iran similar acidity (23.05 ± 2.29 meq/kg). Similar results of acidity have been detected in other studies, Emamifar and Hosseinpanahi [6] determined acidity in Saghez honeys (25.22 meq/kg) and Sanandaj honeys (29.35 meq/kg) and Khanbabaie et al. [5] determined acidity (21.39 meq/kg) in honeys from Kurdistan province of Iran. The pH values of Kurdistan honeys were very close and varied from 3.5 ± 0.0 to 3.9 ± 0.0 . Very close to our detected pH values were also pH values (3.86 and 3.87) detected by Khanbabaie et al. [5] and Emamifar and Hosseinpanahi [6] in honeys from Kurdistan province of Iran.

3.2. Bioactive Compounds

3.2.1. Total Phenolic Content

The results showed that the determined total phenolic contents (mg GAE/100 g) in Kurdistan honeys varied greatly, from 30.8 ± 3.9 to 73.6 ± 0.7 , as presented in Table 4. The lowest concentration (mg GAE/100 g) was detected in honey sample from wild bees from Karah. Total phenolic content of Kurdistan honeys was approximately 1.5-times higher than total phenolic content of Czech and Slovak honeys. In addition, statistically most significant difference ($p < 0.01$) was detected between total phenolic content of Kurdistan honeys and Czech and Slovak honeys. The values of the total phenolic content determined by us were also higher compared to the results of Emamifar and Hosseinpanahi [6] in Saghez honeys (48.36 mg gallic acid/kg) and Sanandaj honeys (34.22 mg gallic

acid/kg) from Kurdistan province of Iran. The total phenolic content (mg GAE/100 g) of Kurdistan honeys was also higher compared to the total phenolic content of European unifloral honeys presented by Tomczyk et al. [25] in black locust (20 ± 5), rape (21 ± 4), and lime honeys (35 ± 1) honeys directly from beekeepers. The higher total phenolic contents in Kurdistan honeys compared to European honeys and other authors indicated different and specific botanical sources of Kurdistan honeys.

Table 4. Total phenolic content and color of the analyzed Kurdistan honeys.

Samples	TPC (mg GAE/100 g)	Color (mm Pfund)	Color int. (mAU)	Color grade
KH1	57.0 ± 8.6	30.0 ± 3.7	245.0 ± 2.8	white
KH2	73.6 ± 0.7	79.4 ± 5.3	321.0 ± 24.0	light amber
KH3	67.2 ± 4.3	55.8 ± 5.0	354.5 ± 29.0	light amber
KH4	64.3 ± 9.1	49.7 ± 3.7	598.5 ± 46.0	extra light amber
KH5	59.5 ± 7.1	43.0 ± 0.0	435.0 ± 52.3	extra light amber
KH6	61.3 ± 8.2	27.4 ± 1.1	154.0 ± 17.0	white
KH7	48.7 ± 8.1	22.8 ± 0.8	183.0 ± 11.3	white
KH8	34.8 ± 4.6	10.0 ± 0.5	228.5 ± 6.4	extra white
KH9	71.4 ± 8.7	31.9 ± 0.0	513.0 ± 36.8	white
KH10	30.8 ± 3.9	17.4 ± 0.5	195.0 ± 7.1	white
Min.	30.8	10.0	154.0	extra white
Max.	73.6	79.4	589.5	light amber
Median	60.4	30.9	283.0	-

TPC – total phenolic content.

3.2.2. Color and Color Intensity

As well as the total phenolic content, the color (mm Pfund) of Kurdistan honey was a very variable parameter ranging from 10.0 ± 0.5 to 79.4 ± 5.3 ; with the average value 36.7 ± 20.6 . The color of Kurdistan honeys was comparable to the color of Czech and Slovak honeys, in addition non-significant difference ($p > 0.05$) was detected between color of Kurdistan honeys and Czech and Slovak honeys. According to USDA color classification [22], a color of the Kurdistan honey samples varied from extra white to light amber, as presented in Table 4.

The color intensity of the Kurdistan beekeeper honeys ranged from 154.0 ± 17.0 mAU to 589.5 ± 46.0 mAU, with the highest determined value for beekeeper honey (KH4) from Sydky. The color of Kurdistan honeys was very similar to the color of Czech and Slovak honeys; however, the color intensity of Kurdistan honeys was approximately 5-times higher than color intensity of Czech and Slovak honeys. In contrast to color, statistically most significant difference ($p < 0.01$) was detected between color intensity of Kurdistan honeys and Czech and Slovak honeys. These findings were in great agreement with results of color intensity (mAU) of Greek honeys, according to their botanical origin: pine (405 ± 135) > fir (289 ± 89) > thyme (209 ± 71) > orange blossom (164 ± 49) reported by Karabagias et al. [26]. Observed significant variations in determined values of color intensity indicate the influence of several pre-extraction factors such as presence of various natural plant pigments, pollen grains, minerals, flavonoids, and post-extraction factors such as Maillard products, on the honey color intensity.

4. Conclusions

This paper as first brought a complex evaluation of quality parameters in honeys directly from Kurdish beekeepers from Dohuk and Erbil Governorates of Iraqi Kurdistan. The determined physicochemical parameters and bioactive compounds varied depending on the botanical and geographical origin of honeys. Comparing with the European Union law only two honey samples had diastase activity lower than limit and one sample had free acidity value at the limit. It was found

that some properties of Kurdistan honeys were very similar to the properties of Czech and Slovak honeys, as indicated by the detected statistically non-significant differences between moisture contents, electrical conductivity, diastase activity and color. On the contrary, detected several times higher total phenolic content and color intensity of Kurdistan honeys and the most significant differences ($p < 0.01$) between the analyzed Kurdistan and Czech and Slovak honeys in hydroxymethylfurfural content, total phenolic content and color intensity pointed to the specific properties of honey from Iraqi Kurdistan. Based on the results, it can be concluded that Kurdistan honeys originating from an area with a warmer climate than honeys from Central Europe met the strict requirements of European Union law and even exceeded European honeys in the content of health protective phenolic substances.

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