Caspian Journal of Environmental Sciences

Online ISSN: 1735-3866
Print ISSN: 1735-3033

Palynological, physicochemical, and organoleptic analysis of honey from different climate zones of Kazakhstan

Gaukhar Moldakhmetova[1,2,*], Ravil Kurmanov[3], Maxat Toishimanov[2], Kadyrbay Tajiyev[1], Ulzhan Nuraliyeva[1,2], Zhanar Sheralieva[1], Kamshat Temirbayeva[1,4], Zhulduz Suleimenova[2]

1. Kazakh Research Institute of Livestock and Fodder Production, 51 Zhandosov Str., 050035, Almaty, Kazakhstan
2. Kazakh National Agrarian Research University, 8 Abay Ave., 050010, Almaty, Kazakhstan
3. Institute of Geology, Subdivision of the Ufa Federal Research Centre of the Russian Academy of Sciences, Ufa, K. Marx Str., 16/2, 450077, Russian Federation
4. al-Farabi Kazakh National University, 71 al-Farabi Ave., 050040, Almaty, Kazakhstan

** Corresponding author's Email: gaukhar.moldakhmetova@list.ru*

ABSTRACT
The article presents the results of palynological and physicochemical analysis of monofloral and polyfloral honey from different climate zones of Kazakhstan. Cotton, buckwheat, camelthorn, Tamarix, sunflower, sainfoin, and raspberry monofloral honey samples were analyzed. For the first time, the relationship between the results of the palynological analysis and some physicochemical values of honey quality indicators was shown. Thirteen samples of fresh honey of various botanical and geographical origins were collected and their basic physicochemical properties were studied, including the mass fraction of water, sucrose, and reducing sugars, free acidity, pH, diastase number (Schade unit), and electrical conductivity. Their organoleptic properties were evaluated. As a result of the conducted research, it was established that the honey samples are high-quality natural products that meet the regulatory requirements of the Codex Alimentarius (Standard for Honey, CXS 12-1981).

Keywords Honey, palynology, Organoleptic properties, Physicochemical analysis.
Article type: Research Article.

INTRODUCTION
There are about 200 thousand bee colonies in the Republic of Kazakhstan; the country produces more than 15 thousand tons of honey every year (Statistical data of Kazakhstan). In the international arena, the leaders in honey production are China (466 thousand tons of honey annually) and Turkey (104.1 thousand tons annually), and the main melliferous plants are sunflower, rapeseed, chestnut, thyme, and citrus. Iran ranks third on the list (80.0 thousand tons annually). In Argentina (150 thousand tons annually), the main melliferous plants are sweet clover, sunflower, eucalyptus, and citrus. Ukraine (68.0 thousand tons annually) is the leader in European beekeeping. In the USA (66.9 thousand tons annually), most beekeepers receive income not from selling honey but from almond pollination. On average, 200 g honey per inhabitant is produced in the country annually. Russia, India, Mexico, and Brazil produce on average 60.5 thousand tons annually. According to the World Federation of Beekeeping Associations, in these countries, one person consumes on average 1 kg honey annually (Diasamidze & Loginova 2018). In Kazakhstan, one person on average consumes only 50 g honey and 36 kg sugar annually (Maikanov & Mustafina 2013). Determining the quality and naturalness of honey is an important task for protecting human health from the negative effects of fake honey (Zaikina 1999). One of the main criteria for the control of the quality and naturalness of honey is its physic0ochemical parameters such as sugar content, water content, and

Caspian Journal of Environmental Sciences, Vol. 21 No. 3 pp. 543-553 Received: Dec. 19, 2022 Revised: March 06, 2023 Accepted: April 28, 2023
DOI: 10.22124/CJES.2023.6931

Publisher: University of Guilan,

others, which are widely used to characterize honey from different botanical regions (Persano *et al.* 1995; Serrano *et al.* 2004; Ebrahimi *et al*. 2023). Palynological analysis of honey allows determining its botanical and geographical origin by counting the amount of pollen contained in it. Palynological analysis of honey was the first method used to study the quality of honey. The earliest works were carried out by R. Pfister in 1895 (D'Albore 1998). Who reported the content and composition of pollen in Swiss, French, and other European honey. The foundations of the method were laid by Zander (1935). The palynological method of analysis is based on the diagnosis of the pollen composition.

The obtained results provide comprehensive information on the botanical source: based on the predominant and single pollen, a list of the main and accompanying melliferous plants from which honey was collected is compiled. This also allows identifying the geographical origin of honey (Kurmanov 2021; Ebrahimi *et al*. 2022). Organoleptic evaluation allows determining the botanical origin of honey, as well as identifying and quantifying its defects (fermentation, impurities, or foreign odors and tastes). It also plays an important role in determining product standards and the appropriate control of botanical names or other specific indicators (Piana *et al.* 2004). In the case of honey, organoleptic analysis was first used in France based on traditional methods by the Gonnet team (Gonnet & Vache 1979; Gonnet & Vache 1998). Kazakhstan is characterized by a significant variety of natural and climatic conditions. Most of the country is occupied by steppes and deserts. The quality of honey directly depends on the type of plants from which the nectar is collected. In Kazakhstan, over 1,000 species of melliferous plants, almost all flowering plants, are pollinated by bees (All about bees and beekeeping). Beekeeping has reached its greatest development in mountainous areas. Here it is based on rich natural honey-bearing lands. In the northern steppe regions, where buckwheat and sweet clover crops are becoming more widespread, beekeeping has also achieved significant development. There are very few bees in the central and western regions of the country, but unused honey-bearing lands can also be found here (Minkov 1974). There are five soil and vegetation zones in Eastern Kazakhstan: alpine, mountain-forest, mountain-forest-steppe, mountain-steppe, and semi-desert. This contributes to the formation of the structure of sown areas with the inclusion of priority of melliferous crops, such as oilseed flax, sunflower, rapeseed, buckwheat, vegetables, melons, safflower, and mustard with annual sowing on an area of up to 500 thousand hectares. In the southeast, there are alpine, mountain-forest, steppe, desert-steppe, and desert zones. The structures of sown areas are formed with the inclusion of priority of melliferous crops, including sunflower, oilseed flax, rapeseed, buckwheat, vegetables, melons, and safflower, with annual sowing on an area of up to 170 thousand hectares. In April-June, from the wild vegetation of the lowest strip of the mountains, the yellow star-of-Bethlehem, willow, foxtail lily, chives, sainfoin, flat pea, sweetvetch, motherwort, meadow sage, and marshmallow have honey-bearing significance (Rib 2012). The characteristic features of the climate of Southern Kazakhstan are aridity and continentality. The Southern region includes desert-steppe and desert soil and vegetation zones. This limits the structure of sown areas to melliferous vegetables, melons, camelthorn, fountainbush (*Psoralea*), safflower, and mustard with annual sowing on an area of up to 120 thousand hectares (Rib 2013). The most interesting are Tamarix, camelthorn, and fountain bush honey produced in semi-desert and steppe zones of Southern Kazakhstan. Honey is a sweet viscous liquid with a pleasant smell, obtained by honey bees from flower nectar or honeydew (sweet discharge on leaves of plant or animal origin).

Thus, there are two types of natural honey: floral and honeydew. Fake honey is sugar honey processed by bees, as well as honey from sweet juices of fruits and vegetables or artificial honey. Honey can be of any color, from light yellow to brown, depending on the type of plant from which the bees collected nectar. Flower honey is usually divided into homogeneous (monofloral), obtained from the nectar of flowering plants of the same genus or species (linden, buckwheat, sunflower, etc.), and polyfloral, obtained from a variety of flowering plants. The latter is distinguished by the place of growth of the plants – meadow, taiga, mountain, or steppe (Beekeeping). Different approaches have been used to characterize the geographical and botanical origin of honey, and there is no universal approach to distinguish one kind from another. Thus, several approaches, in the form of palynological, physicochemical, and organoleptic analysis, complement each other and are reliable for determining the botanical and geographical origin of honey. Bogdanov *et al.* (2004) suggest that currently, the most reliable determination of the botanical and geographical origin of honey can be achieved only by interpreting organoleptic, palynological, and physicochemical data. Conducting physicochemical, palynological, and organoleptic analyses of honey samples from different climate zones of Kazakhstan was the main purpose of this study.

MATERIALS AND METHODS

Sampling

Flower honey samples were used as the research material. They were selected from apiaries located in six natural and climate zones of the southern, southeastern, and eastern regions of Kazakhstan. The collection of samples was carried out according to the sampling rules (https://adilet.zan.kz/rus/docs/V1500011618#z43). In total, 13 honey samples collected from the following climate zones were selected for palynological, organoleptic, and physicochemical analyses: desert, semi-desert, foothill, mountain, forest-steppe, and steppe.

Palynological analysis

Palynological analysis was carried out at the Ufa Federal Research Center of the Russian Academy of Sciences, Institute of Geology. Micro-preparations from the samples were made according to the generally accepted method. 10 g honey was mixed with 20 mL water in a conical tube of 50 mL. Then the solution was centrifuged for 10 minutes at 1,000-2,500 RPM. Afterward, the filler liquid was drained, and the precipitate was transferred to a slide with a wire loop and evenly distributed over an area of 20 × 20 mm (Von der Ohe *et al.* 2004). Atlases of pollen grains were used to identify pollen (Kurmanov 2019).

Physicochemical analysis

During the physicochemical analysis, seven indicators were studied: the mass fraction of water, sucrose, reducing sugars, free acidity, pH, diastase number (Schade unit), and electrical conductivity. The mass fraction of water in honey was determined based on the refractometric method using an IRF-454 refractometer. The mass fractions of reducing sugars and sucrose were determined using the AgilentCary60 spectrometric method, determining the optical density of a solution of potassium ferrocyanide after it reacted with reducing sugars. The diastase number was determined using an Agilent Cary 60 ultraviolet spectrometer at a wavelength of 590 nm. The Schade unit was measured based on the method of spectrometric determination of the amount of substrate split under the conditions of an enzymatic reaction, followed by its calculation. Acidity (pH) was measured using ConsortC931. Free acidity was determined using the titrimetric method 0.1M NaOH to pH 8.2 (Codex Alimentarius).

Organoleptic analysis

When isolating monofloral honey samples, we considered their organoleptic properties (Piana *et al.* 2004).

RESULTS

The main criterion for honey quality affecting its market value is its botanical and geographical origin. To determine the pollen shares of the melliferous plants in the studied samples of Kazakh honey, we carried out a palynological analysis of polyfloral honey (Table 1). Out of 13 samples, we identified five kinds of polyfloral honey collected from four climate zones, where the number of taxa ranges from 21 to 39 denominations. The obtained pollen compositions of polyfloral honey samples were characterized by a very high taxa diversity. The spectra contained pollen of mountain, forest, and steppe melliferous plants, as well as various crops and weeds.

In the composition of honey from the forest-steppe zone, the largest share was that of *Caragana* sp. pollen (20.1%), from the semi-desert zone, followed by *Onobrychis* sp. (27.2%) and *Melilotus* sp. pollen (23.1%). In the sample from the foothill zone, the share of pollen from more than one plant did not reach 20.0%; the largest share was from *Hedisarum* sp. (16.9%) and *Salvia* sp. (11.6%). In the mountain honey samples, pollen from *Caragana* sp. (from 8.2 to 23.4%), *Salix* sp. (from 8.2 to 27.4%), and Apiaceae (*A. sylvestris* and *A. deccurens*; from 0.8 to 7.2%) were predominant. Table 2 shows pollen shares in the composition of monofloral kinds of honey (cotton, sainfoin, Tamarix, camelthorn, viper's bugloss, sunflower, and raspberry), where *Gossypium hirsutum*, *Tamarix* sp., and *Alhagi* sp. exhibited underrepresented pollen (<45.0%). All other melliferous plants belonged to the species with normally presented pollen (>45.0%).

The smallest share of the pollen of the main melliferous plant was observed in sample No. 6, where the share of *Psoralea drupacea* and cotton pollens were 37.3% and 9.3% respectively. The low cotton pollen content in the sample may be due to the presence of extrafloral nectaries. In sample No. 7, *Halimodendron halodendron* (49.9%) and *Tamarix* sp. (34.6%) pollens were dominate. This might be the best honey in the desert zone of the country. In samples No. 8 and 10, *Onobrychis* sp. pollen was dominate, i.e., 58.4 and 71.8%, respectively. The main accompanying pollens were *Echium vulgare* and *Eremurus* sp. (24.3%). In honey sample No. 13, *Echium vulgare* pollen was prevailed (49.3%). It was accompanied by a high proportion of *Onobrychis s*p. pollen (24.3%). Sample

No. 9, presented as buckwheat honey, was dominated by *Helianthus annuus* pollen (52.2%). The share of *Fagopyrum esculentum* pollen grains did not exceed 19.2%. According to the results of the palynological analysis, the sample was determined to be sunflower honey. Sample No. 11 was distinguished by the largest variety of pollen types in the spectrum. In total, pollen of 27 taxa was found here. The proportion of *Rubus idaeus* pollen grains was 45.0%.

Table 1. Results of palynological analysis of polyfloral honey.

№	1	2	3	4	5
Zone	**Mountain**	**Mountain**	**Forest-steppe**	**Foothill**	**Semi-desert**
Melliferous plants	**Share of pollen in the spectrum (%)**				
Caragana sp.	23.4	8.2	20.1	6.4	0.6
Salix sp.	27.4	8.2	6.5	2.3	2.9
Rubus idaeus	8.9	4.3	7.2	1.7	0.6
Lamium sp.	1.6	5.3	2.2	0.6	-
Amoria montana	0.8	-	1.4	4.1	1.7
Angelica sylvestris	-	21.6	0.7	7.0	-
Angelica deccurens	-	8.2	-	5.2	-
Fabaceae	-	9.6	1.4	-	-
Salvia sp.	4.0	5.3	1.4	11.6	-
Eremurus sp.	-	0.5	-	-	1.7
Hedysarum sp.	-	-	-	16.9	2.3
Allium sp.	0.8	7.2	-	0.6	-
Fagopyrum esculentum	3.2	-	-	-	-
Linaria vulgaris	8.9	-	-	-	1.2
Echium vulgare	-	2.4	0.7	10.5	-
Onobrychis sp.	5.6	5.8	0.7	8.1	27.2
Melilotus sp.	-	-	2.9	6.4	23.1
Barbarea sp.	-	-	7.9	1.2	18.5
Helianthus annuus	-	-	1.4	-	-
Total number of taxa, pcs.	28	32	39	31	21

Table 2. Results of palynological analysis of monofloral honey.

No.	6	7	8	9	10	11	12	13
Type of honey	**Cotton**	**Tamarix**	**Sainfoin**	**Sunflower**	**Sainfoin**	**Raspberry**	**Camelthorn**	**Viper's bugloss**
Zone	**Semi-desert**	**Desert**	**Foothill**	**Forest-steppe**	**Steppe**	**Forest-steppe**	**Desert**	**Semi-desert**
Melliferous plants	**Share of pollen in the spectrum (%)**							
Gossypium hirsutum	9.3	-	-	-	-	-	-	-
Psoralea drupacea	37.3	-	-	-	-	-	-	-
Sophora sp.	16.9	2.0	-	-	-	-	-	-
Tamarix sp.	11.0	34.6	-	-	-	-	7.3	-
Halimodendron halodendron	-	49.9	-	-	-	-	9.2	-
Alhagi sp.	-	-	-	-	-	-	1.1	-
Lythrum sp.	-	0.3	-	-	-	-	69.1	
Echium vulgare	-	-	24.3	0.8	-	-	-	49.3
Onobrychis sp.	-	-	58.4	0.4	71.8	8.5	-	24.3
Helianthus annuus	-	-	-	52.2	-	3.9	-	-
Fagopyrum esculentum	-	-	-	19.5	-	-	-	-
Rubus idaeus	-	-	-	1.6	0.5	45.0	-	1.1
Caragana sp.	-	-	-	1.6	0.9	1.6	-	-
Salvia sp.	-	-	0.4	2.8	-	0.8	-	0.7
Total number of taxa, pcs.	25	20	26	24	13	27	13	14

Alhagi sp. pollen turned out to be extremely underrepresented (1.1%) in monofloral camelthorn honey. Camelthorn, as well as cotton, had extrafloral nectaries, which affected the content of their pollens. In general, *Lythrum* sp. pollen grains (69.1%), a coastal plant widely distributed in oases, dominated the sample. Natural and climate zones and the adaptability of plants to these conditions did not affect monofloral honey. For example, in the desert zone, the leaders among melliferous plants were Tamarix and Alhagi, except for field plants. This feature may be due to their wide distribution and the absence of other strong melliferous plants in the desert zone. Monofloral honey obtained from field crops included sainfoin, sunflower, raspberry, and cotton, which may be due to the large acreage. Honey also contains pollen from non-nectariferous plants. In the 13 samples studied, the number of non-nectariferous plants ranged from 1 to 10 taxa. The highest shares in pollen spectra were those of Chenopodiaceae, *Artemisia* sp., *Fumaria* sp., *Potentilla* sp., and *Filipendula ulmaria* pollens (>10.0%). The lowest percentages of pollen from non-nectariferous plants were found in samples from desert and semi-desert zones. Physicochemical and organoleptic analyses were carried out to determine the quality of the honey samples. Table 3 shows the results of the physicochemical analysis of monofloral and polyfloral samples. The main important indicators of honey quality are the mass fraction of water, as well as sucrose and the diastase number. All indicators were within the norm. The mass fraction of water ranged from 13.4 to 16.6%, which is within the norm.

Table 3. Results of physicochemical analysis of polyfloral and monofloral honey samples.

№	Indicators, unit of measurement	Zone	Water(%), under	Sucrose (%), under	Reducing sugars (%), over	Free acidity (meq kg^{-1}), under	pH	Diastase number, Schade units, at least	Electrical conductivity (mSm cm^{-1}), under
	NORM		**20**	**5**	**65**	**40**		**8**	**0.8**
				Results for polyfloral honey					
1	Polyfloral	mountain	15.0	3.13	82.12	20	3.89	17.5	0.09
2	Polyfloral	mountain	16.8	3.44	72.36	19	3.88	19.4	0.04
3	Polyfloral	forest-steppe	17.6	2.88	78.50	20	3.88	13.0	0.09
4	Polyfloral	foothill	15.0	3.04	81.20	27	4.05	37,2	0.05
5	Polyfloral	semi-desert	15.6	1.69	67.54	34	4.06	7.7	0.06
				Results for monofloral honey					
6	Cotton	semi-desert	15,6	1,40	67.21	33	4.26	8.9	0.59
7	Tamarix	desert	13.4	1.54	68.87	31	4.22	9.8	0.11
8	Sainfoin	foothill	15.2	2.54	69.66	23	4.23	8.1	0.03
9	Sunflower	forest-steppe	16.6	2.83	74.63	24	4.15	20.6	0.27
10	Sainfoin	steppe	14.2	2.87	75.61	25	4.11	13.5	0.22
11	Raspberry	forest-steppe	16.6	2.69	69.84	22	4.03	17.4	0.37
12	Camelthorn	desert	15.0	2.02	67.36	30	4.19	10.1	0.07
13	Viper's bugloss	semi-desert	15.0	3.04	81.22	34	4.26	22.4	0.05

The mass fraction of sucrose ranged from 1.40 to 3.04%, which exhibiting the high quality of honey; the mass fraction of reducing sugars ranged from 67.4 to 81.2%, indicating the maturity and naturalness of honey. The mass fracture of water and sucrose was below the norm. The pH was much lower than the upper limit of the acidic medium (from 3.88 to 4.26). The diastase number was below the norm in sample No. 5 (7.7 Schade units). Similar low diastase rates were also characteristic of sample No. 8 (8.1 Schade units). Given the similarity of the pollen compositions of these two samples, this fact may be associated with the feed base. Low diastasis was also found in monofloral cotton, Tamarix, and camelthorn honey, verifying our judgment. Bees do not have time to saturate the collected nectar with enzymes when honey is collected in a short time on large arrays of a nearby melliferous plant. The best polyfloral honey (sample No. 4) was obtained from the foothill zone with a diastase number of 37.2 Schade units. Mountainous and foothill honey (samples No. 1-3) exhibited the lowest free acidity (19-20 meq kg^{-1}), as well as the lowest pH (3.88-3.89).

The highest indicators of free acidity were characteristic of monofloral and polyfloral honey from the desert and semi-desert zone (samples No. 5-7, 12, and 13; 30-34 meq kg^{-1}). All eight types of monofloral honey were natural, mature, and possess good qualities. The amount of free acids did not reach the norm, and the pH of honey was in the range of 4.03-4.26, exhibiting high acidity. The diastase number in all samples was above the norm, showing good quality, naturalness, and maturity. High diastase numbers were observed in sainfoin, raspberry sunflower, and viper's bugloss samples (13.5, 17.4, 20.6, and 22.4 Schade units respectively). High diastase rates in sunflower honey may be due to a significant proportion of buckwheat pollen. Buckwheat honey always has an increased diastasis. The highest electrical conductivity was found in sample No. 6 (0.59 mSm cm^{-1}). Our hierarchical cluster analysis identified the correlation between samples, which allows for classification by physicochemical parameters. The Pearson correlation coefficient denotes the correlation between the main physicochemical indicators.

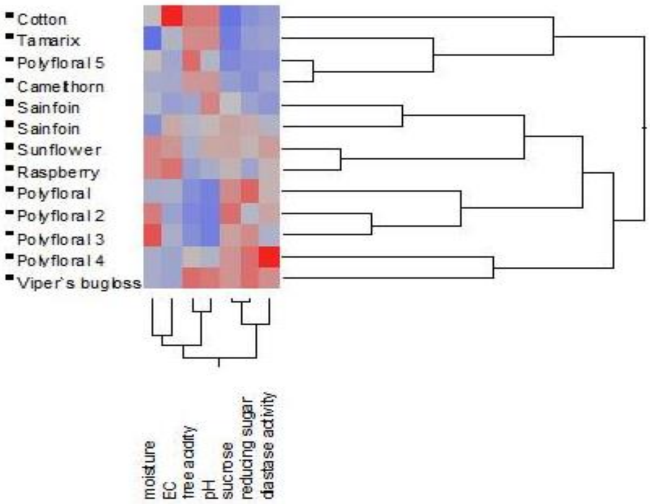


Fig. 1. Hierarchical clustering analysis of honey samples using the Ward method.

Cluster analysis was based on the physical and chemical characteristics. Three separate cluster groups of honey were identified based on their physicochemical indicators. The first hierarchical group included cotton, Tamarix, camelthorn, and polyfloral No. 5 honey samples, collected in desert and semi-desert zones. These regions are characterized by a sharp continental climate and low humidity. The low mass fraction of sucrose, reducing sugars and the low diastase number united these samples into one group. The second cluster group included two samples of sainfoin, raspberry, and sunflower honey. Although both sainfoin samples were collected in different regions, Almaty and Turkestan, both came from the steppe zone.

Sunflower and raspberry samples were from Eastern Kazakhstan and Almaty regions, both as forest-steppe zone. The third cluster group included polyfloral honey samples. All samples were collected in the foothill zone of Eastern Kazakhstan and Almaty regions. The polyfloral sample from the Almaty region came from the same mountainous system as other samples from the Eastern Kazakhstan region. According to the palynological indicators (Table 1), the caragana pollen share mainly ranged from 8.2 to 23.4%. This group is characterized by the high mass fractions of water and reducing sugars. This may be due to the fact that a large variety of melliferous plants prevail in this region. The fourth cluster group included samples collected from the mountain and semi-desert zones of the Tien Shan Mountains (Almaty region).

These samples differ from the rest by the highest values of the diastase number, free acidity, and share of reducing sugars. We used hierarchical cluster analysis to classify obtained data based on physicochemical indicators (Adaškevičiūtė *et al.* 2019; da S. Sant'ana *et al.* 2020). After clustering, we divided all obtained data into three main groups, reflecting that this analysis significantly contributes to classification based on physicochemical composition.

Table 4. Pearson correlation table, variable significance level (*p≤0.05, **p≤0.01, ***p≤0.001).

	Water	Sucrose	Reducing sugars	Free acidity	pH	Diastase activity	Electrical conductivity
water	1.0000	0.3625	0.0536	-0.5072	-0.5409	0.0914	0.1484
sucrose	***	1.0000	0.7515	-0.6974	-0.5735	0.6455	-0.3845
reducing sugars	***	*	1.0000	-0.3230	-0.3968	0.7035	-0.3405
free acidity	**	*	***	1.0000	0.7316	-0.1862	0.1424
pH	**	*	**	*	1.0000	-0.2485	0.2732
diastase activity	***	*	*	***	***	1.0000	-0.1880
electrical conductivity	***	***	***	***	***	***	1.0000

The most positive correlations were between the mass fractions of sucrose and reducing sugars ($p = 0.75$ and $p < 0.003$ respectively), as well as the diastase number and the mass fractions of sucrose ($p = 0.64$ and $p < 0.001$ respectively) and reducing sugars ($p = 0.70$ and $p < 0.007$ respectively; Fig. 2). Thus, a change in the mass fraction of sucrose strongly affects the indicator of the mass fraction of reducing sugar. The change in the diastase number strongly correlates with the indicators of the mass fractions of sucrose and reducing sugar. It follows that all three indicators are strongly interrelated. Strong negative correlations were found between the mass fraction of sucrose and free acidity ($p = -0.69$ and $p < 0.008$ respectively), that is, a change in the sucrose index does not affect free acidity. Other researchers also confirm the correlation between characteristics (Ratiu *et al.* 2020; Pereira *et al.* 2020).

The results of the organoleptic evaluation of honey based on the main four indicators are presented in the form of diagrams (olfactory, color, taste, and physical appearance; Fig. 3). According to organoleptic properties, all samples met the requirements; no defects were detected (Fig. 3). In cotton honey, the intensity of the smell was weakly expressed. In terms of tasting qualities, it exhibited a moderately sweet taste with a pleasant aftertaste, characteristic of cotton honey. The color intensity ranged from pale light to light yellow. Physical appearance consisted of small crystals. Visual evaluation of the Tamarix honey sample: light, bright yellow; olfactory evaluation: intense, without extraneous odors, warm vegetable aroma; taste evaluation: average sweetness, no bitterness; physical appearance evaluation: medium crystallized.

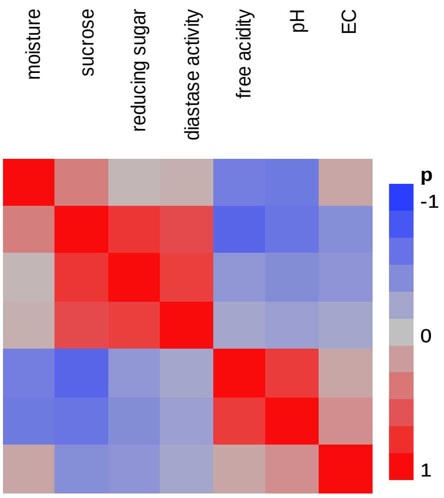
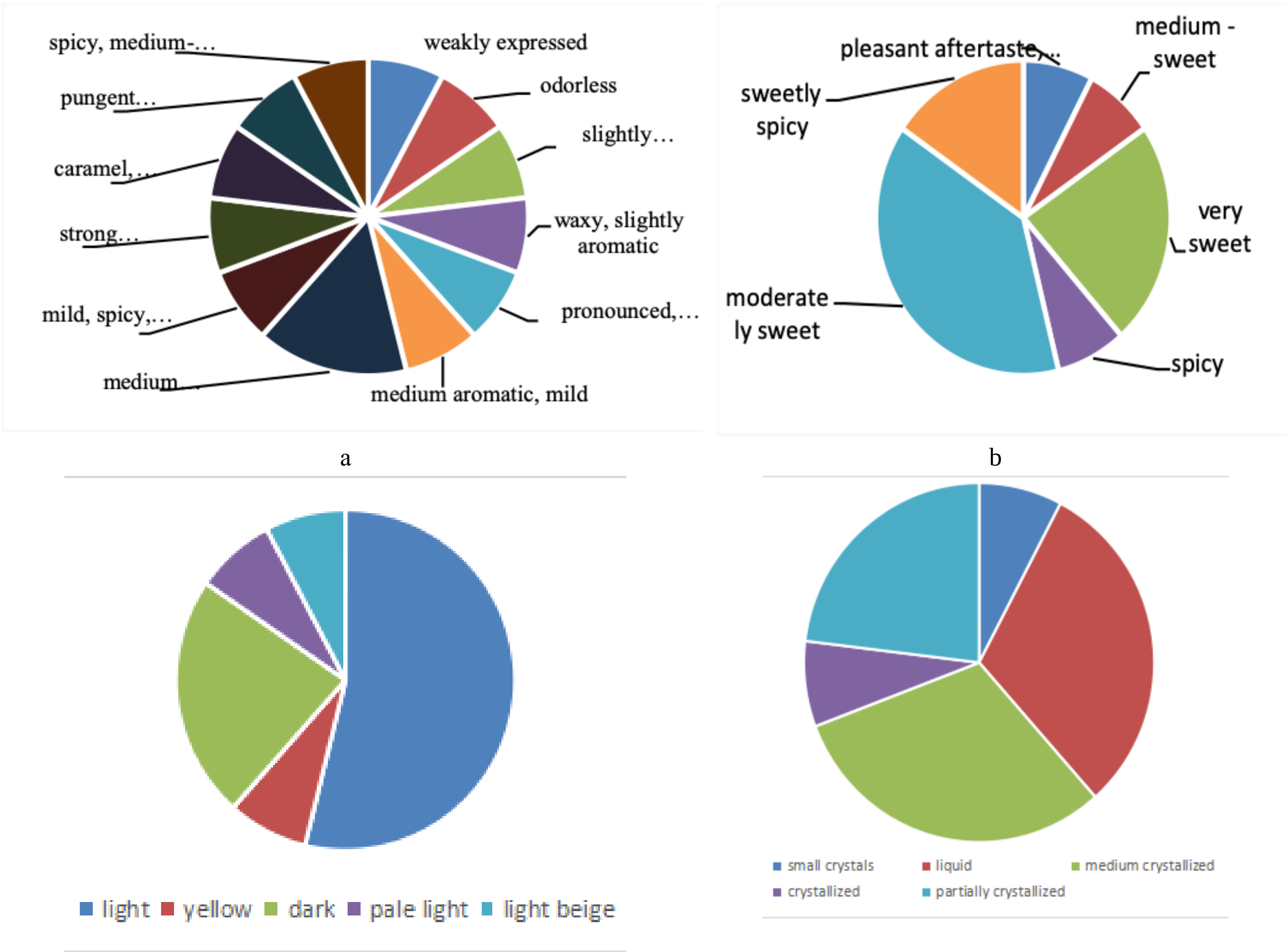


Fig. 2. Pearson correlation heat-map. The small panel on the right shows the correlation coefficients. Positive correlations are indicated in red, and negative correlations are indicated in blue.

Two samples of sunflower and polyfloral honey came from the same farm but different natural and climate zones. The mountain polyfloral honey was slightly aromatic with a waxy aroma, spicy, and medium crystallized. The second sample from the forest-steppe zone had a pronounced herbaceous smell. The raspberry and polyfloral honey samples collected from the forest-steppe zone, displayed a sweet taste and moderate aromatic intensity, and were liquid. In the mountain zone, polyfloral honey with moderate aromatic intensity was light in color and differed from the rest in its liquid consistency. In the samples of sainfoin honey from different zones (steppe and foothill), there was a weakly pronounced slightly herbaceous aroma. The color ranged from light to yellow. According to the taste evaluation, it was sweet and spicy. Based on its physical properties, it was medium crystallized. Two samples of polyfloral honey from different zones (mountain and semi-desert) were moderately aromatic, moderately sweet, and liquid. We only observed a color difference: the mountain sample was dark in color, while the semi-desert one ranged from light to light yellow. The camelthorn monofloral honey from the desert zone exhibited a sharp aroma, light color, moderate sweetness with a long aftertaste, and no bitterness. It was partially crystallized. There were no special characteristics in the viper's bugloss honey. It was spicy, moderately aromatic, and moderately sweet. In most cases, honey obtained from sainfoin, viper's bugloss, and sage was light. Thus, according to the results of organoleptic analysis, it was found that six samples were light and moderately sweet with average crystallization. Three samples were dark in color, strongly sweet, and liquid. These qualities are of great importance in determining marketable kinds of honey.



c d

Fig. 3. Organoleptic properties: (a) olfactory, (b) taste, (c) color, and (d) appearance (n = 13).

DISCUSSION

To study the quality of flower honey, 13 honey samples were taken from eight natural and climate zones in Kazakhstan. Five samples, classified as polyfloral were collected from four natural climate zones (mountain, foothill, semi-desert and forest-steppe). Eight samples, classified as monofloral were collected from five natural climate zones (desert, semi-desert, steppe, forest-steppe and foothill). This shows the botanical abundance and diversity of melliferous plants, and due to the variety of pollen spectra, affecting the quality and naturalness of honey. In the composition of polyfloral honey, there are from 21 to 39 taxa, while in the composition of monofloral honey, there are from 13 to 26 taxa. These indicators show naturalness and high quality. If bees are bred in the foothill and mountain climate zones, honey is mainly obtained from nectar collected from various types of plants. Therefore, it is called polyfloral. If one melliferous plant prevails in the composition (45% and higher, except for species with underrepresented pollen), then such honey is called monofloral, which is provided by species with high honey productivity and large areas of growth.

Most often, these are various crops (cotton, sainfoin and sunflower), weeds (viper's bugloss), and wild desert species (camelthorn and Tamarix). In monofloral honey samples with normally represented pollen, the share of *Echium vulgare* pollen grains reached 49.3%, *Rubus idaeus* up to 45.0%, *Caragana* sp. up to 49.9%, and *Onobrychis* sp. up to 71.8%. Approximately the same pollen shares were found in studies of the Kyrgyz region [25]. Cotton pollen was present in sample No. 1 and amounted to 9.3%. In Tajik cotton honey, the share of *Gossypium* pollen was 15.0% (Kurmanov & Bobokalonov 2015). In our studies, the best indicator of 71.8% was observed in sainfoin honey collected in the steppe zone. This indicator was also established, in Kyrgyz studies, where sainfoin honey exhibited 72.0% and other types of honey, on average 13.0-66.0% (Ishenbayeva *et al.* 2021). Of the 13 honey samples, six samples corresponded to their names, which was confirmed during the palynological analysis. In four samples, the name was not indicated. In the honey presented as buckwheat, the share of buckwheat pollen was only 19.5%. The sample was identified to be sunflower honey with a share of sunflower pollen of 52.2%. The honey from the semi-desert zone in Southern Kazakhstan presented as Psoralea honey, was found to be cotton honey with a cotton pollen share of 9.3%; the cotton pollen was underrepresented by at least 1.2% (Kurmanov *et al.* 2014). The sample of honey from the mountain zone presented as Caragana honey turned out to be polyfloral honey with a share of willow pollen of 27.4% and Caragana pollen of 23.4%. Based on physicochemical indicators, the polyfloral honey from the foothill zone in the Almaty region displayed the best properties with the indicator of the diastase number of 37.2 Schade units. The lowest indicator of 7.7 Schade units was found in the polyfloral honey from the semi-desert zone in the same region. The diastase number is an indicator of the quality of honey. In monofloral honey, the diastase number was higher than the minimum value of 8 Schade units, which indicates diastase activity and good quality of honey. The diastase numbers were slightly lower (17.5-19.4 Schade units) in the polyfloral honey from the mountain zone than those observed in other studies (Kadyrova & Smanalieva 2017).

These values characterize the activity of enzymes and the safety and quality of honey, indicating its good biological activity. The mass fraction of water in all samples did not exceed the norm (13.4-17.6%). The content of reducing sugars ranged from 67.21 to 82.12%, which also corresponds to the norm. The free acid content of the studied samples ranged from 19 to 34 meq kg^{-1}. Similar data are given by Maykanov *et al.* (2019). The highest electrical conductivity was found in the sample of semi-desert cotton honey (0.59 mSm cm^{-1}). The lowest indicator was found in the mountain monofloral honey (0.03 mSm cm^{-1}). The organoleptic properties of honey had no deviations from the norm or special differences associated with the zones they came from. However, samples No. 9 and 11 were distinguished by their pronounced aroma, which may be due to the diversity of associated melliferous plants, since both samples having been taken from the forest-steppe zone. They had a strong sweet taste, and were intensely dark in color. Sample No. 12 exhibited a pungent odor. Sample No. 7 from the same zone had no smell and was moderately sweet and light in color. Both samples came from the desert zone of the Kyzylorda region. Thus, all samples represent mature natural honey. All samples were divided into four clusters based on their physicochemical parameters, considering the influence of natural and climate zones and the share of pollen of melliferous plants.

CONCLUSION

The results of palynological, physicochemical, and organoleptic studies of the samples allow us to conclude that mature natural honey with good taste and medicinal properties is produced in Kazakhstan. Different kinds of honey produced from local melliferous plants, including camelthorn, Tamarix, and *Psoralea* can become Kazakh brands. All samples demonstrated high taste qualities without any defects. In the future, it is necessary to determine the content and level of pesticides, antibiotics, heavy metals, radiation, etc. residue. Such research motivates beekeepers to produce environmentally friendly natural honey.

ACKNOWLEDGMENTS

This study was funded by the Ministry of Agriculture of the Republic of Kazakhstan, BR10764957 "Development of technologies for effective management of the selection process in beekeeping".

REFERENCES

Adaškevičiūtė, V, Kaškonienė, V, Kaškonas, P, Barčauskaitė, K & Maruška, A 2019, Comparison of physicochemical properties of bee pollen with other bee products. *Biomolecules*, 9: 819. https://doi.org/10.3390/biom9120819.

All about bees and beekeeping. https://ylejbees.com/medonosy/1900-medkazax.

Beekeeping. https://allbusiness.kz/zoo/4-pchelovodstvo.html.

Bogdanov, S, Ruoff, K & Persano, O 2004, Physico-chemical methods of characterization of single-flowered modes: a review», *Apidology*, 35: C4-C17, DOI: 10.1051/apido:2004047

Codex Alimentarius 1981, Standard for Honey CXS 12 (Adopted in 1981, Revised in 2001)

D'Albore, G 1998, Mediterranean Melissopalynolog, UniversitàdegliStudi di Perugia, 466 p.

da S Sant'ana, R, de Carvalho, CAL, Oda Souza, M, de A Souza, B & de S Dias, F 2020, Characterization of honey of stingless bees from the Brazilian semi-arid region. *Food Chemistry*, 327: 127041.

Diasamidze, E & Loginova, V 2018, Features of work on the world honey market.

Ebrahimi, Y, Ramírez-Coronel, AA, Baqir Al-Dhalimy, AM HC, Alfilm, R, Al-Hassan, M, Fadhel Obaid, RA, Alameri, A, Rastiani, F, Khaledian, Y, Shokri, S 2022, Contamination of honey products by Clostridium botulinum spores and fungi along with their effects on human health. *Caspian Journal of Environmental Sciences*, 20: 1143-1148.

Ebrahimi, Y, Ramírez-Coronel, AA, Al-Dhalimy, AMB, Alfilm, RHC, Al-Hassan, M, Obaid, RF, Alameri, AA, Rastiani, F, Khaledian, Y & Shokri, S 2023. Effects of honey and bee venom on human health. *Caspian Journal of Environmental Sciences*, 21: 245-249.

Gonnet, M & Vache, G 1998, Descriptive sensory analysis of some monofloral honeys from France and Europe. Ed. Abeille de France, Paris, France.

Gonnet, M & Vache, G 1985, The taste of bread, Ed. UNAF, Paris, France.

Gonnet, M & Vache, G 1992, The taste of hone, Apimondia, Bucarest.

Gonnet, M & Vache, G 1979, Honey tasting technique and search for an objective rating and classification system to assess their quality through sensory analysis, 27th Apimondia International Apic. Congress, Athens, pp. 499-506, https://adilet.zan.kz/rus/docs/V1500011618#z43.

Ishenbayeva, NN, Kerimaliev, ZhK & Abdurasulov AH 2021, Palynological characteristics of monoflora honey of the Republic of Kyrgyzstan. Vestnik Bashkir State Agrarian University, 1: 68-72.

Ishenbayeva NN, Kurmanov RG, Kerimaliev ZhK & Giniyatullin MG 2021, Research of quality indicators of different types of honey in Kyrgyzstan. Vestnik Bashkir State Agrarian University, 4: 72-78.

Kadyrova, K & Smanalieva, Zh 2017, Determination of physico-chemical properties of honey from mountainous and lowland regions of Kyrgyzstan. *Maniac Journal of Engineering*, 5. www.journals.manas.edu.kg

Kurmanov. R 2021, Organoleptic and palynological analysis of honey: the review of the modern condition of techniques, characteristic of the monofloral Russian honey type, Geography. *Innovations and Food Safety*. DOI: 10.31677/2311-0651-2020-29-3-19-31Corpus ID: 233646234

Kurmanov, RG & Bobokalonov, DM 2015, Pollen characteristics of Tajik honeys, *Kishovarz*, 1: 32-34.

Kurmanov, RG & Ishbirdin, AR 2014, Melissopalynology. Ufa: RIC Bash GU, 128 p.

Kurmanov, RG 2019, Geographical and botanical origin of Bashkir honey. Atlas of pollen. Ufa: Mir Pechati. 440 p.

Maikanov, B & Mustafina, R 2013, Monitoring of honey production in the Republic of Kazakhstan», Materials of the Republican scientific and theoretical conference "Seifullin readings - 9: A new vector of development of higher education and science" dedicated to the day of the First President of the Republic of Kazakhstan, 1: 230-232.

Maykanov, BS, Mustafina, RH, Auteleeva, LT & Hornet, EA 2019, The quality of bee honey produced in Central and Eastern Kazakhstan. *Bulletin of Science*, 2: 111-124.

Minkov, S 1974, Melliferous plants of Kazakhstan. Almaty, Kainar, 204 p.

Pereira, JR, da R Campos, AN, de Oliveira, FC, Silva, VRO, David, GF, da Silva, JG Nascimento, WWG, Silva, MHL & Denadai, AML 2020, Physical-chemical characterization of commercial honeys from Minas Gerais, Brazil. *Food Bioscience*, 36: 100644.

Persano, O, Piazza, M, Sabatini, A & Accorti, M 1995, Characterization of unifloral honeys. *Apidologie*, 26: 453-465. https://hal.archives-ouvertes.fr/hal-00891311.

Piana, M, Oddoa, L, Bentabol, A, Bruneauc, E, Bogdanov, S & Guyot Declerckc, C 2004, Sensory analysis applied to honey: state of the art. *Apidologie*, 35: 26-37.

Ratiu, IA, Al Suod, H, Bukowska, M, Ligor, M & Buszewski, B 2020, Correlation Study of Honey Regarding their Physicochemical Properties and Sugars and Cyclitols Content. *Molecules*, 25: 34. https://doi.org/10.3390/molecules25010034.

Rib, R 2013, Melliferous plants of Kazakhstan", Ust-Kamenogorsk. Advertising Digest, 672 p.

Rib, R 2012, Beekeeper of Kazakhstan, Ust-Kamenogorsk. Media Alliance, 776 p.

Serrano, S, Villarejo, M, Espejo, R & Jodral, M 2004, Chemical and physical parameters of Andalusian honey: classification of citrus and eucalyptus honeys by discriminant analysis. *Food Chemistry*, 87: 619–625, DOI: 10.1016/J.FOODCHEM.2004.01.031

Von der Ohe, W, Oddo, L, Piana, M, Morlot, M & Martin P 2004, Harmonized methods of melissopalynology, *Apidologie*, 35: 18-25.
Zaikina, V 1999, Examination of honey and methods of detecting its falsification, Moscow: pp.98-102.
Zander, E 1935, Pollen design and determination of origin in honey from honey, Reichsfachgruppe beekeepers, Berlin.

Bibliographic information of this paper for citing:
Moldakhmetova,G, Kurmanov, R, Toishimanov, M, Tajiyev, K, Nuraliyeva, U, Sheralieva, Z, Temirbayeva, K, Suleimenova, Z 2023, Palynological, physicochemical, and organoleptic analysis of honey from different climate zones of Kazakhstan. Caspian Journal of Environmental Sciences, 21: 543-553.