

Quality Assessment of Honey in Three Different Geographical Areas from Republic of Moldova

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Abstract

One of the empirical and image products of the Republic of Moldova is bee honey. Its assortment is due to the variety of landforms, as well as the diversity of flora specific to geographical regions. During the Covid-19 pandemic, domestic consumers had limited access to bee honey. This was caused by the restrictions imposed in order to organize fairs and agricultural markets which are one of the main sources for the purchase of bee products in the Republic of Moldova. At the same time, the analysis of trademarks in supermarkets highlighted the preferences of honey consumption as follows: polyfloral honey—28.57%, lime honey—20.40% and acacia honey—14.28%. In order to evaluate the quality of honey from small producers and highlight the specific characteristics of geographical areas, 60 samples were analyzed that included 3 types of honey: polyflora, sunflower and linden collected from 3 different geographic areas: Soroca area (North), area Ungheni (Center), Stefan Voda area (South). Honey samples were declared harvest of 2020. They were analyzed physico-chemically using methods provided by national and EU standards. The results obtained from the analysis of pollen in honey confirm the botanical origin declared by beekeepers and allowed to highlight the types of pollen specific to each area. Following the determination of qualitative indices: reaction with ethyl alcohol, with resorcinol; insoluble matter, cereal flour, gelatin and starch, it was found that the most inconsistencies were found in linden honey. Some indicators were close to the maximum permissible values specified in regulatory documents. The water content found in the honey samples was quite varied, and ranged from $16.05\% \pm 0.11\%$ to $19.89\% \pm 0.13\%$, but these samples were within the limits of the standards. Total acidity ranged from 6.19 ± 0.13 to 27.20 ± 0.03 which falls within the established norms (up to $50.00 \text{ cm}^3 \text{ NaOH}$ solution in (milliequivalents) per 100 g of honey). According to the SIE Lab space, all samples have a yellowish tint, this is indicated by positive values on the b^* axis. However, honey samples from the southern region of Moldova showed the presence of greenish pollen, as evi-

denced by the reduced values on the a^* axis. Our research reveals the quality level of honey from three different areas of the Republic of Moldova and the variation of quality parameters due to factors such as geographical region, climatic conditions, botanical origin and handling or storage conditions.

Keywords

Honey, Physico-Chemical Indices, Geographical Areas, Republic of Moldova, Covid-19 Impact

1. Introduction

According to the latest report from the European Commission on the beekeeping market, the European Union is the world's second largest producer of honey after China, with an average production of 230.000 tons per year and a total of 17.5 million hives, owned by 650.000 beekeepers. The self-sufficiency rate in the European Union is 60%, the rest of the demand being covered by imported honey. The Republic of Moldova has, in turn, a rich tradition regarding honey production, with an average of 4.000 tons per year, which is mostly exported to the European Union [1].

Regarding the consumption of bee products, it differs depending on the tradition of each country [2], but also depending on sociodemographic factors such as gender, age, family structure, education, income, occupation and residence [3]. Honey is an emblematic product of the Republic of Moldova [4]—this positioning determines the particular interest of the beekeeping sector [5]. The export of honey in 2019 in tonnes is shown in **Figure 1**, in 2020 there was an increase in the export of honey by 14% [6].

It should be mentioned that a maximum of 15% of the total volume of honey produced in the Republic of Moldova is consumed locally. The price of honey sold to individuals is twice as high as the wholesale price offered by large intermediaries. However, low wholesale prices, as well as high production costs, stop investment in the honey sector. At present, about 85% of the production volume is exported. For our country, the main market is the European Union, which assimilates over 90% of exported honey, while in 2015, the ratio was 98%. The main honey destinations in the Republic of Moldova are Italy, Germany, France, Slovakia, but also smaller, but still considerable markets, such as Romania, Poland, Denmark, etc. [8].

Its sustainable development contributes not only to socio-economic development, but also to rural development and the maintenance of biodiversity. From an economic point of view, beekeeping is an income-generating and market-creating activity with a high rate of return on investment [9].

In the context of the mentioned above, the study of the beekeeping sector can contribute to the tracking process of the path of products from producer to consumer and to the development of strategies for all the involved actors. Existing

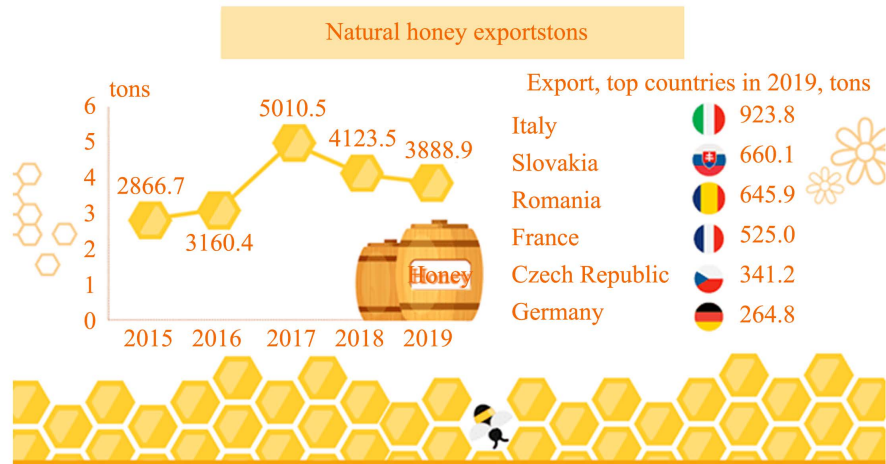


Figure 1. Honey export from the republic of Moldova [7].

scientific research draws attention to several problems in the beekeeping sector, namely counterfeiting of honey and fraud [10] of the botanical and geographical origin of the product. According to a report of the EU Food Fraud Network, honey is listed third in the ranking of potentially counterfeit products in the European Union [11]. Additionally, the consumers are not sufficiently informed about the quality and integrity of the honey they consume [12].

The geographical position of the territory of Moldova gives its climate a pronounced continental character, with frequent occurrences of drought. Climatic peculiarities lead to the presence of three agro-climatic regions: north, central and south. The following is typical for the northern region: the sum of the average daily active temperatures in 2.700°C - 3.000°C is limiting; the maximum rainfall is 451 - 711 mm/year; temperature above 10°C is equivalent to 167 - 176 days/year. For the central agro-climatic region, compared to the northern region, the following is typical: higher level of average daily active temperatures (100°C - 200°C higher); longer period with temperatures higher than 10°C (6 - 10 days more) and less precipitation (14 - 93 mm less). The southern region is warmer and less humid than the northern area. The sum of the average daily active temperatures here is up to 3.300°C and the duration of the period with the temperature higher than 10°C is longer, 11 - 12 days, and the amount of precipitation is lower than in the northern area (70 - 120 mm/year; Hydrometeorological Center 1982) [13].

Given that the Republic of Moldova is an agrarian country and bee honey is one of the country's image products, keeping quality under control and adjusting to European standards becomes a very important issue [14].

It is important to note that honey from the Republic of Moldova is produced by both industrial beekeepers and small-scale artisanal beekeepers, who work closely with consolidators, processors and exporters. The honey obtained is genuine, subject to strict quality controls throughout the production cycle, to ensure purity in every drop. In order to meet the growing demand of consumers of

organic products, Moldovan producers, consolidators and processors tend to turn their production, increasingly, into organic production. At the same time, the Republic of Moldova meets the standards of the European Union for the quality of honey, in accordance with Directive 110/2001 of the European Council. The country is a “certified third party” by the EU for compliance with drug and pesticide residue analysis. All disease and parasite control products that are used in Moldova are EU approved. Moldovan honey exporters offer buyers a range of packaging options, from single-serving packages to 300 kg barrels. Packaging options also include jars weighing between 30 g and 950 g, as well as single-dose packs of 8 - 20 g [15] [16].

At the same time, the National Beekeeping Development Program in the Republic of Moldova for 2020-2026 clearly mentions the general objective, namely: increase the number of bees, increase the productivity of hives and develop the range of bee products by applying modern technologies and promoting the practice of professional beekeeping in order to increase the production and export volume up to 8.2 thousand tons in 2026 [8]. The specific objectives regarding the development of the beekeeping sector and the achievement of the general objective are presented in **Figure 2**.

Based on the specific objectives mentioned above, the vector of beekeeping research must be firmly oriented towards the physico-chemical indices and the authenticity of honey because these indicators are essential for the certification

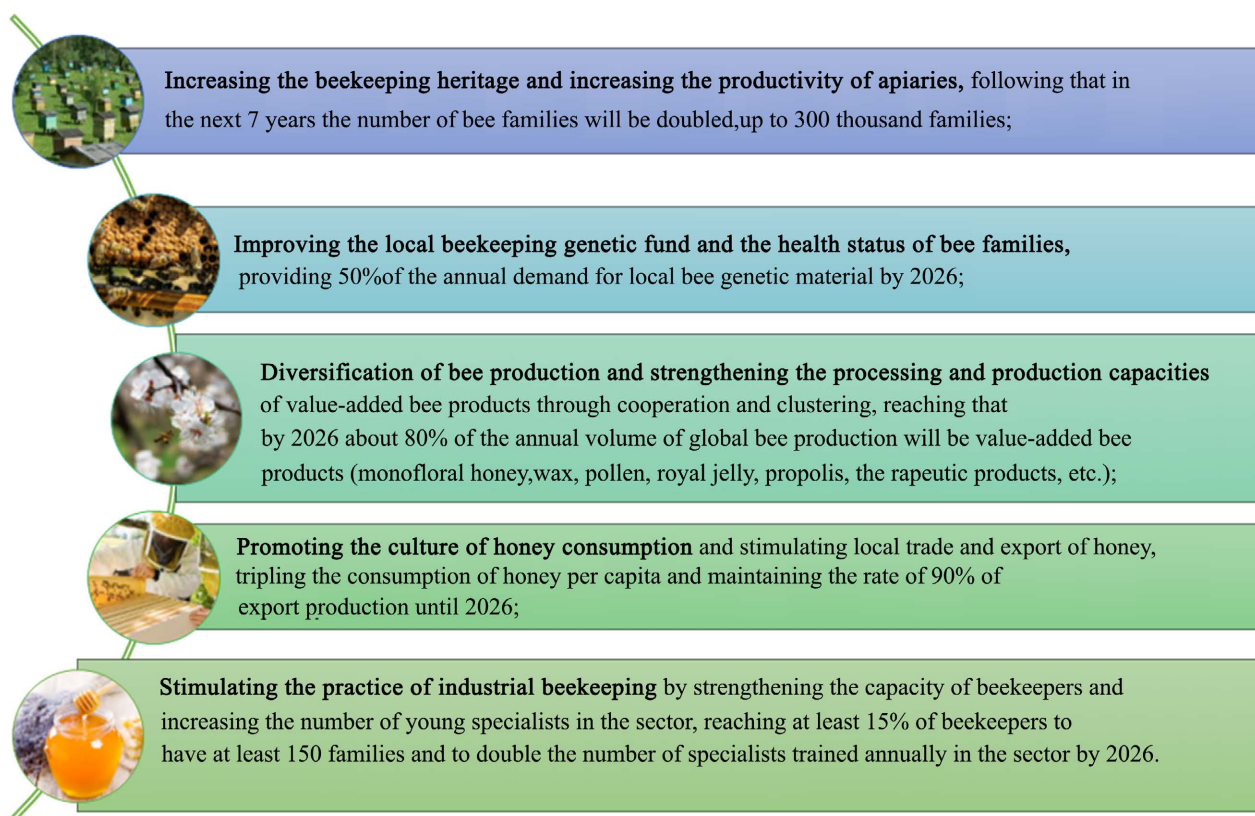


Figure 2. Specific objectives regarding the development of the beekeeping sector in the Republic of Moldova.

process and determine the quality of honey. This, in turn, represents the success of bee products on both the local and foreign markets [17].

In this study, three different types of bee honey collected from three geographical regions of the Republic of Moldova were analyzed, namely from the northern, central and southern areas. The objectives of this study were: to highlight the types of bee honey in major Moldovan supermarkets available to consumers during the Covid-19 pandemic; to analyze and compare physico-chemical indices from bee honey of different botanical origin collected in different regions of the Republic of Moldova, to determine and compare the content of polyphenols, flavonoids and DPPH between bee honey of the same botanical origin taken from different geographical regions of the Republic Moldova; to compare the data obtained with the data in the literature.

2. Materials and Methods

The research was conducted between November 2020-March 2021. The assortment of honey on the shelves of the largest supermarket chains in the Republic of Moldova (in the capital Chisinau) was examined (Nr1, Kaufland, Metro cash & carry, Linella, Bonus, Fourchette), which were available to consumers during the pandemic. Determination of physico-chemical parameters was performed in the laboratories of the Department of Food and Nutrition of the Faculty of Food Technology of the Technical University of Moldova. During the research, the honey samples were kept in laboratory conditions, packed in glass jars, hermetically sealed, at a temperature of $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

Honey samples

The study included nine honey samples from three different apiaries from the Republic of Moldova, which include three types of the most specific honeycombs, namely polyfloral honey, sunflower honey and linden honey. Samples of honey were collected in 2020 and come from different geographical regions of the Republic of Moldova: Soroca, Ungheni and Stefan Voda. The characteristics of the geographical origin and abbreviations of the samples are presented in the **Table 1**.

In order to highlight the physico-chemical indices have been determined: Mass fraction of water, Inverted sugar, Sucrose, pH, Total acidity, Ash content, Water insoluble matter, presence of cereal flour, presence of starch. All results were evaluated on the basis of Codex Alimentarius Commission (CAC, 2001) [18] and harmonized methods of the International Honey Commission (**Table 2**).

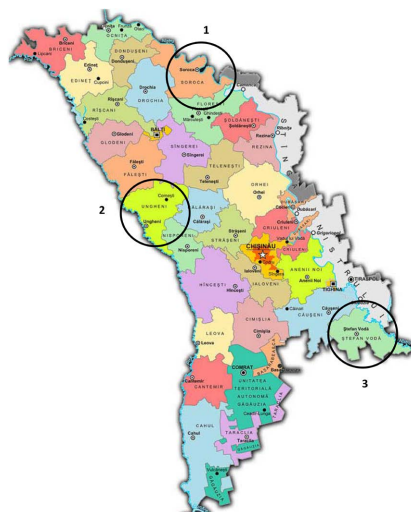
Palynological analysis It was performed by microscopic analysis according to the method of Chuttong and al. (2018) [19].

Mass fraction of water was determined using Honey humidity refractometer ATAGO 4422 PAL-22S, 12.0% to 30.0%, acc. $\pm 0.2\%$.

The pH of the samples was measured potentiometrically at 20°C using a pH-meter (HANNA 2211 - 02) bench meter with an electrode holder. Aqueous solutions

Table 1. Characteristics of the geographic origin of the examined honey samples.

Nr.	Geographical area	Geographical position	Honey samples
1	North of Moldova, Soroca area	48°09'21"N 28°17'51"E, The altitude is about 45 m above sea level	Polyfloral honey (n = 7)
			Sunflower honey (n = 5)
			Linden honey (n = 5)
2	Center of Moldova, Ungheni area	47°11'15"N 27°47'45"E, The altitude is about 62 m above sea level	Polyfloral honey (n = 11)
			Sunflower honey (n = 8)
			Linden honey (n = 7)
3	South of Moldova, Ștefan Vodă area	46°30'55"N 29°39'47"E The altitude is about 141 m above sea level	Polyfloral honey (n = 7)
			Sunflower honey (n = 5)
			Linden honey (n = 5)

**Table 2.** Physico-chemical indices and the considered references.

Nr.	Physico-chemical indices	Specifications
1	Mass fraction of water	max. 20.0
2	Inverted sugar	min. 65.0
3	Sucrose	max. 8.0
4	pH	3.24 - 6.1
5	Total acidity	max. 4.0
6	Ash	max. 0.5
7	Water insoluble matter	absent
8	Presence of cereal flour	absent
9	Presence of starch	absent

of honey were prepared by dissolving 1 g of honey in 10 mL distilled water (10% w/v).

Total acidity is determined by the potentiometric method. The water content is determined by measuring the refractive index at 20°C at using an abbe-type refractometer.

To determine the *invert sugar* (by the Elser method) it was taken into account that glucose and fructose, in the free state, have the ability to reduce copper sulfate in an alkaline and hot environment, which it transforms into copper oxide.

The amount of copper oxide that is formed under specific working conditions

is proportional to the concentration of the two reducing sugars in the solution to be researched.

Total *ash content* was determined according to the method of incineration of honey samples. The ash content is a quality criterion for honey origin, the blossom honeys having a lower ash content than the honeydew ones.

For the determination of *sucrose* (by Elser method) the direct reducing sugar was determined before and after inversion (acid hydrolysis), and from the difference sucrose is calculated.

Determination color parameters

The chromaticity coordinates [L^* -lightness, a^* (positive values)-redness/greenness (negative values), b^* (positive values)-yellowness/blueness (negative values)] of honey samples were measured using an optical sensor colorimeter (Chroma Meter CR-400 Head) in an equal volume of native honey. Prior measurements, the instrument was calibrated with a black and white standard plate.

C -chroma describes the vividness or dullness of a colour—in other words, how close the colour is to either grey or the pure hue. Chroma values were determined using the formula on the basis of a^* and b^* color parameters:

$$C^* = \sqrt{a^{*2} + b^{*2}} ;$$

H° -hue is how we perceive an object's colour—red, orange, green, blue, etc. The same holds for hue, angle which was determined using the formula:

$$H^\circ = \arctan\left(\frac{b^*}{a^*}\right) ;$$

Chroma and hue angle values were determined according to K. Karabagias *et al.* (2018) [20].

The color of honey was also determined through spectrophotometric measurement of 50% honey solution (m/v) with absorbance reading at 635 nm. The results of absorbance were correlated with the Pfund scale (Table 3) according to Scholz *et al.* (2020) [21].

Statistical Analyses. All laboratory methods were run in 3 replicates and the results were expressed as means with standard deviations (SD). The significant differences represented by letters were obtained by a one-way analysis of variance (ANOVA) followed by Tukey's honestly significant difference (HSD) post

Table 3. Color category to the Pfund scale.

Color	Pfund (mm)
Water white	≤8
Extra white	8 ≤ 17
White	17 ≤ 34
Extra light amber	34 ≤ 50
Light amber	50 ≤ 85
Amber	85 ≤ 114
Dark amber	>114

hoc test ($P < 0.05$). Static data processing was performed using the ANOVA program, mean and standard deviation were calculated using Microsoft Excel 2019.

3. Results and Discussions

3.1. Honey Brands in the Major Supermarkets of Moldova

To get a better understanding of what the choice of honey was consumer during a pandemic, assortment studies were conducted on supermarket chains authorized to sell during a severe pandemic.

The quantitative ratio of varieties of honey sold in the largest supermarkets in Chisinau is shown in the **Figure 3**. During the research period polyfloral honey occupied the largest share in the assortment—28.57%. Linden honey ranks second in the ranking—20.40%. Also, a significant share in the total assortment is occupied by acacia honey—14.28%.

The quantitative ratio of varieties of honey is due to the preferences of local consumers.

The examination of the label revealed the presence of such information as: labeling, name and type of product, year of collection, name and location of the manufacturer, weight, energy value per 100 g, storage period and conditions, date of packing. It was established that not all labels indicated the documents according to which the product was manufactured.

The volume of the product varied from 12 g to 1 kg, and the honey was packed in polyethylene bags for single use or in glass jars. In all the surveyed supermarkets, only 6 producers were identified, while in Moldova more than 7.8 thousand beekeepers are registered.

It should be noted that there have been no studies of consumer preferences of various types of honey in the Republic of Moldova. Research conducted in Romania (neighboring country with close geo-climatic and social conditions) shows that the most preferred honey is polyfloral as in the case of consumers preferences from the Republic of Moldova. On the second position is acacia honey (Popescu *et al.*, 2019) [22]. On the other hand, consumers in Ukraine, the

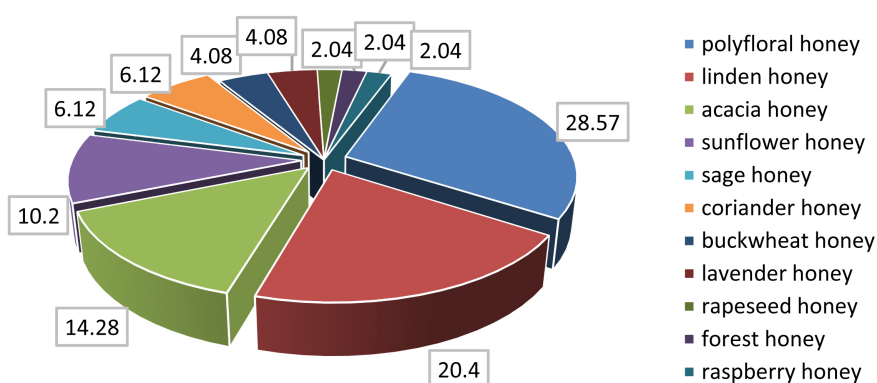


Figure 3. The quantitative ratio of varieties of honey sold in supermarkets in Chisinau.

second neighboring country that has a common border with the Republic of Moldova in the west, prefer the consumption of polyfloral honey and sunflower [23].

After analyzing the results obtained, the following problems can be identified that prevent local beekeepers from expanding their marketing boundaries:

- ✓ According to the data, the production of honey in the Republic of Moldova has grown by 63% in five years, and it should be noted that the leading position in the production of honey was taken by the private sector [24] [25]. This fact contributes to increased competition between honey producers.
- ✓ During the pandemic, all state requirements and programs for the quality and improvement of the beekeeping industry were available only in electronic form. But not all small producers have the ability and skill to use them.
- ✓ In addition to the constraints and connectivity issues due to the pandemic, small-scale honey producers are constrained by tariff barriers and local duties.
- ✓ And also, the situation was complicated by the increase in the volume of imports of cheap honey, as a result, for many domestic beekeepers, the problem of selling the produced honey has become urgent.

Considering the above, in the following studies, three types of honey were used that were established as the most consumed in the severe period of the Covid-19 pandemic in the Republic of Moldova, Chisinau.

3.2. Pollen Analysis

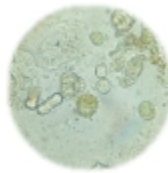


Determining the floral origin of honey can be done by analyzing the pollen profile that allows us to affirm or refute the information declared by beekeepers. The frequency of pollen grains identified in the analyzed honey is presented in **Table 4**.

In the floral honey was identified a large number of pollens that was found decreasing in the honey from the three geographical areas of the Republic of Moldova (in the northern area there are 7 types of pollen, center 6 and south 4). In sunflower honey, *Helianthus annuus* pollen was dominant and the maximum amount was in the northern area (7.00% - 74.05%). In linden honey the content of the dominant pollen varied (from 47.11% - 47.69% for the southern area to 80.05% - 81.90% in the northern area). The obtained results confirm the botanical origin of the honey declared by the beekeepers and we can assume that the honey was filtered and packaged in accordance with the requirements and norms.

3.3. Determination of Honey Adulteration

In order to determine the adulteration of the analyzed honey samples, the following qualitative indices were determined: reaction with ethyl alcohol, with resorcinol; water-insoluble matter, cereal flour, gelatin and starch. The results in **Table 5** denote that 3 of out of the 60 analyzed samples presented water-insoluble substance. This was confirmed by the white precipitate and the intense reddish

Table 4. The pollen analysis results of honey samples from different areas of Moldova.

Types honey	Geographical region	Pollen type and frequency	Examples of images of dominant pollen
Polyfloral	North (n = 7)	<i>Tilia cordata</i> —25.03% - 26.15% AP <i>Aster alpinus</i> —17.31% - 17.92% AP <i>Acer platanoides</i> —17.05% - 17.82% AP <i>Heliánthus ánnuus</i> —12.53% - 13.21% IMP <i>A. aitchisonii</i> —12.07% - 12.92% IMP <i>Tilia americana</i> —8.22% - 8.99% IMP <i>Aesculus hippocastanum</i> —8.11% - 8.93% IMP	
	Center (n = 11)	<i>Rubus idaeus</i> —27.66% - 28.94% AP <i>A. alatipes</i> —17.54% - 18.03% AP <i>Salix acmophylla</i> —16.23% - 18.21% AP <i>Taraxacum officinale</i> —15.02% - 16.02% IMP <i>Trifolium pratense L.</i> —12.00% - 13.02% IMP <i>Fragaria</i> —11.84% - 12.05% IMP	
	South (n = 7)	<i>Rubus idaeus</i> —37.11% - 38.02% AP <i>Trifolium pratense L.</i> —21.02% - 22.05% AP <i>Salix acmophylla</i> —22.05% - 22.89% AP <i>Robinia pseudoacacia</i> —19.05% - 19.92% AP	
Sunflower	North (n = 5)	<i>Heliánthus ánnuus</i> —73.00% - 74.05% DP <i>Trifolium pratense L.</i> —18.02% - 19.11% AP <i>A. alatipes</i> - 9.04%—10.11% IMP	
	Center (n = 8)	<i>Heliánthus ánnuus</i> —69.09% - 70.22% DP <i>A. alatipes</i> —14.05% - 14.21% IMP <i>Acer platanoides</i> —10.33% - 10.95% IMP <i>Trifolium pratense L.</i> —7.02% - 7.89% IMP	
	South (n = 5)	<i>Heliánthus ánnuus</i> —61.11% - 62.06% DP <i>Acer platanoides</i> —10.05% - 10.87% IMP <i>Trifolium pratense L.</i> —17.00% - 18.05% AP	
Linden	North (n = 5)	<i>Tilia cordata</i> —80.05% - 81.90% DP <i>Trifolium pratense L.</i> —19.05% - 20.05% AP	
	Center (n = 7)	<i>Tilia americana</i> —49.05% - 50.00% DP <i>Heliánthus ánnuus</i> —13.00% - 13.05% IMP <i>Cichorium intybus</i> —13.02% - 13.02% IMP <i>Quercus robur</i> —11.05% - 11.84% IMP <i>Acer platanoides</i> —7.02% - 7.05% IMP	
	South (n = 5)	<i>Tilia americana</i> —47.11% - 47.69% DP <i>Heliánthus ánnuus</i> —13.15% - 13.5% IMP <i>Cichorium intybus</i> —13.01% - 13.09% IMP <i>Trifolium pratense L.</i> —11.55% - 12.00% IMP <i>Acer platanoides</i> —7.00% - 7.98% IMP	

Dominant pollen/DP > 45%; accompanying pollen/AP 15% - 45%; important minor pollen/IMP 3% - 15%; minor pollen/MP > 1% [26].

Table 5. Determines the adulteration of honey samples from the republic of Moldova.

Types honey	Geographical region	Reaction with ethyl alcohol	Reaction with resorcinol	Water-insoluble matter, %	Cereal flour	Gelatin	Starch
Polyfloral	North (n = 7)	Negative	Negative	Negative	Absent	Absent	Absent
	Center (n = 11)	Negative	Negative	Negative	Absent	Absent	Absent
	South (n = 7)	Negative	Negative	Negative	Absent	Absent	Absent

Continued

Sunflower	North (n = 5)	Negative	Negative	Negative	Absent	Absent	Absent
	Center (n = 8)	Negative	Negative	Negative	Absent	Absent	Absent
	South (n = 5)	Negative	Negative	Negative	Absent	Absent	Absent
Linden	North (n = 4)	Negative	Negative	Negative	Absent	Absent	Absent
	North (n = 1)	White precipitate	Intense Red Colour	0,09	Absent	Absent	Present
	Center (n = 5)	Negative	Negative	Negative	Absent	Absent	Absent
	Center (n = 2)	White precipitate	Intense Red Colour	0,08	Absent	Absent	Present
	South (n = 5)	Negative	Negative	Negative	Absent	Absent	Absent

color that appeared when reacting with ethyl alcohol and resorcinol. The intense red color is obtained in response to the reaction with resorcinol and we can affirm that the honey was subjected to heat treatment or stored in inadequate conditions without respecting the temperature regime [27].

However, water-insoluble substances with a content of 0.09% and 0.08%, respectively, were also identified in these samples, but the quantity was within the permissible limit (maximum 0.1%). Other results obtained from the research that captured our attention were the presence of starch in the same 3 samples of linden honey from North and Centre of the Republic of Moldova. The results presented above showed that these honey samples were susceptible to external interference. Probably the water-insoluble substance represents pollen.

3.4. Physico-Chemical Indices of Honey

In the last 10 years in the Republic of Moldova has doubled honey production and the authorities announced major plans in this area. In this context, it is necessary to be kept under control the quality of local honey. At the same time, honey from the Republic of Moldova is known as a good quality product that requires continuous monitoring [28] [29].

The water content found in the honey samples was quite varied, and ranged from $16.05\% \pm 0.11\%$ for sunflower honey from the south to $19.89\% \pm 0.13\%$ for linden honey from the northern area (Table 6). These samples were within the limits of the standards (~20%) according to the International Quality Regulations [18].

It is known that a higher water content could cause unwanted fermentation of honey during storage and formation of acetic acid [30]. At the same time, the water content in honey depends on various factors, including the harvest season, the degree of maturity reached in the hive, geographical and environmental factors [31] [32].

Total acidity, pH and ash content were determined for the purpose of highlighting and comparison with International Requirements. Thus, we observe that the total acidity ranged from 6.19 ± 0.13 for linden honey from North part of Republic of Moldova to 27.20 ± 0.03 for polyfloral honey from south part which falls within the established norms (up to $50.00 \text{ cm}^3 \text{ NaOH}$ solution in (milliequivalents) per 100 g of honey).

Table 6. Physico-chemical indices of honey samples from the republic of Moldova.

Types honey	Geographical region	Water content, %	Total acidity, cm ³	pH	Ash, %	Inverted sugar, %	Sucrose, %
Polyfloral	North (n = 7)	18.02 ± 0.11 ^g	27.03 ± 0.02 ^a	4.08 ± 0.10 ^e	0.39 ± 0.03 ⁱ	81.02 ± 0.11 ^b	0.65 ± 0.02 ^g
	Center (n = 11)	17.99 ± 0.07 ^a	26.60 ± 0.11 ^a	4.05 ± 0.11 ^d	0.41 ± 0.04 ^a	80.17 ± 0.13 ^f	0.71 ± 0.11 ^g
	South (n = 7)	17.02 ± 0.19 ^c	27.20 ± 0.03 ^g	4.06 ± 0.12 ^a	0.35 ± 0.07 ^g	82.13 ± 0.04 ^a	0.98 ± 0.03 ^c
Sunflower	North (n = 5)	17.52 ± 0.17 ^g	26.20 ± 0.12 ⁱ	4.05 ± 0.06 ^c	0.38 ± 0.02 ^c	83.00 ± 0.10 ^b	1.49 ± 0.07 ^g
	Center (n = 8)	16.86 ± 0.24 ^e	24.38 ± 0.02 ^b	4.01 ± 0.03 ^g	0.49 ± 0.04 ^a	81.21 ± 0.12 ^d	1.51 ± 0.11 ^a
	South (n = 5)	16.05 ± 0.11 ^b	22.09 ± 0.01 ^b	3.68 ± 0.04 ^b	0.31 ± 0.03 ^f	76.91 ± 0.14 ^g	1.69 ± 0.13 ^d
Linden	North (n = 5)	19.89 ± 0.13 ^a	6.19 ± 0.13 ^d	4.14 ± 0.05 ⁱ	0.28 ± 0.06 ^a	75.98 ± 0.11 ^c	0.84 ± 0.01 ^c
	Center (n = 7)	18.78 ± 0.09 ^g	19.10 ± 0.02 ⁱ	3.24 ± 0.06 ^c	0.21 ± 0.02 ^e	74.11 ± 0.02 ^b	1.12 ± 0.06 ^f
	South (n = 5)	18.70 ± 0.89 ^b	9.98 ± 0.03 ^c	3.32 ± 0.10 ^g	0.50 ± 0.11 ⁱ	83.91 ± 0.01 ^b	1.41 ± 0.12 ^a

Note: a-i: in each column different letters mean significant differences ($P < 0.05$).

It should be noted that the acidity of honey is a quality parameter that helps to assess the freshness of honey [15]. Thus, based on the acidity values of experimental samples, it was established that the analyzed honey was harvested in 2020.

The pH of the honey samples ranged from 3.24 ± 0.06 to 4.14 ± 0.05 and the average pH of the examined honey sample was 3.81. The allowed ash content in honey is a maximum of 0.5%. In two researched samples the ash content was at the maximum allowable limit [18].

The content of invert sugar and sucrose in honey are essential indicators of their quality [16] [33]. The average mass fraction of sugar was 80.06% (74.11% - 83.91%) and the average mass fraction of sucrose was 1.043% (0.65% - 1.69%). These indices fall within the established norms: the mass fraction of invert sugar of at least 65.0% and the mass fraction of sucrose of maximum 8.0%.

Simultaneously it was measured colour by the Chroma meter CR 400. The results presented are shown in Table 7.

The color of honey is characteristic of its floral source due to minerals and other minor components. Exposure to heat and storage time may affect honey's color. Honey appears lighter in color after it has granulated [34].

Table 7 depicted a descriptive analysis color influential physicochemical parameter in CIE Lab space. In accordance with these results using the CIE Lab space, the lowest value of L (lightness) corresponds to the dark honey with mean values for samples of sunflower honey (average 32.45). The samples from the South of Moldova have the least low L value, which indicates the presence of the darkest shades of pollen. The highest L value was noted in polyfloral honey samples (mean 35.4). Samples from the south of Moldova also have the highest L value, which indicates the presence of the lightest shades of pollen.

The difference between kinds of honey in function of the components a^* and b^* are statistical significant ($P < 0.001$). Greenish (negative a^* values) were recorded in polyfloral honey samples from South of Moldova area (-0.56), and

Table 7. Color parameters of honey samples from the Republic of Moldova.

Types honey	Geographical region	L*	a*	b*	Chroma*	Hue°	Color (mmPfund)
		Mean ± SD	Mean ± SD	Mean ± SD			
Polyfloral	North (n = 7)	27.99 ± 0.12 ^g	3.25 ± 0.04 ^b	12.63 ± 0.01 ^g	5.64 ± 0.02 ^g	1.32 ± 0.08 ^e	29 ± 0.03 ^g
	Center (n = 11)	33.03 ± 0.09 ^d	2.27 ± 0.05 ^e	18.96 ± 0.03 ^c	6.52 ± 0.02 ^c	1.45 ± 0.05 ^c	53 ± 0.02 ^a
	South (n = 7)	45.18 ± 0.10 ^a	-0.56 ± 0.04 ⁱ	31.87 ± 0.15 ^a	7.91 ± 0.09 ^a	-1.55 ± 0.03 ^j	43 ± 0.05 ^d
Sunflower	North (n = 5)	31.03 ± 0.01 ^e	1.93 ± 0.05 ^f	17.56 ± 0.01 ^d	6.25 ± 0.04 ^d	1.46 ± 0.09 ^b	37 ± 0.08 ^e
	Center (n = 8)	38.10 ± 0.02 ^c	1.37 ± 0.01 ^g	24.71 ± 0.03 ^b	6.79 ± 0.13 ^b	1.02 ± 0.04 ^g	41 ± 0.02 ^d
	South (n = 5)	28.24 ± 0.15 ^g	3.53 ± 0.03 ^a	11.65 ± 0.03 ^h	5.51 ± 0.10 ^h	1.28 ± 0.07 ^f	39 ± 0.07 ^e
Linden	North (n = 5)	29.39 ± 0.15 ^f	2.66 ± 0.06 ^d	14.75 ± 0.13 ^f	5.90 ± 0.03 ^e	1.39 ± 0.12 ^d	22 ± 0.09 ^g
	Center (n = 7)	30.81 ± 0.29 ^e	3.05 ± 0.07 ^c	16.15 ± 0.11 ^e	6.20 ± 0.01 ^d	1.38 ± 0.19 ^d	38 ± 0.06 ^e
	South (n = 5)	43.46 ± 0.09 ^b	0.90 ± 0.03 ^h	15.96 ± 0.02 ^c	5.81 ± 0.15 ^f	1.51 ± 0.01 ^a	34 ± 0.04 ^e

also the result of linden honey from South area were close to zero (0.90). However, samples from central Moldova showed an average of 3.05, which indicates the presence of reddish pollen [35] [36].

The data of b* axis, representing the positive values a shift toward yellow color, and the negative values a shift toward blue color. All samples had only positive values b. The most yellowish samples were polyfloral honey from south of Moldova (mean values 31.87) followed a sunflower honey from center of Moldova (mean values 24.71).

The Chroma or colorfulness of an area represents the amount of color and increase with the brightness having the clearest honey the higher values of Chroma. The lower values are shown for the dark honey and the highest values are shown for the light honey. The CIELab coordinates were useful for distinguishing monochromatic honeys by hue and color, and for better differentiating between honey varieties [37] [38].

A scale Pfund used in the honey industry to describe the color of honey. Color values presented in Pfund scale (water white, extra white, white, extra light amber, light amber, amber and dark amber) in order to classify honey colors. The colors of the studied samples varied from white to extra light amber, and only polyfloral honey samples from the central part of Moldova were light amber [39].

4. Conclusions

For consumers in the Republic of Moldova, it is characteristic to purchase food products, including bee honey from small local producers, who distribute the products directly from them, through agricultural markets and specialized fairs. Purchasing products in these ways is a national tradition. The preservation of this tradition is due to the consumers' conviction of the high quality of local products, and honey is an empirical product for the given geographical area.

At the same time, one of the major impacts of the Covid-19 pandemic is li-

miting the population's access to food, including honey. The research showed that the assortment of honey and the producers' presence in the main supermarkets in the Republic of Moldova are very limited.

Experimental samples of honey were purchased directly from local beekeepers, who did not have the opportunity to market their products during the Covid-19 pandemic and they were not available in large supermarket chains. For this reason, during the pandemic consumers were limited in choosing a quality local product. The physico-chemical indicators of the studied honey samples fall within the values allowed in both local and international regulations.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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