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ESTIMATION OF THE WORLD BEEKEEPING MARKET

The object of research is the world beekeeping market, the ecological role and physicochemical properties of the quality of honey and beekeeping products.

The problem of generalizing and systematizing the results of research on the global beekeeping market is solved. It is determined that the key factors of market growth are the demand for organic and natural sweeteners in the food industry and beverage production, the excellent natural healing properties of honey and beekeeping products, and the environmental benefits of organic farming.

It is shown that significant global challenges to market development are the reduction of the bee population due to the use of pesticides and the loss of habitat.

It was determined that in 2024, the North American segment was the leader by geographical regions with a revenue share of 40.1%, by product type – the honey segment (88.2%), by application – the food and beverage segment (39.9%), by end user – the food industry segment (54.9%), by sales channels – the supermarket and hypermarket segment (34.7%), by funding distribution – the bee disease prevention segment (29.9%).

It was determined that in 2023, the beehive segment dominated by equipment segments (48.1%), by geographical regions – the Asia-Pacific segment (33.1%).

The physicochemical qualities of honey were studied. The mass fraction of water in the studied samples (Kyiv region, Zhytomyr region, Chernihiv region, Republic of Moldova) of honey ranged from 17.5% to 19.8%, diastase number – from 15.54 to 38.59 Gothe units, electrical conductivity – from 0.349 Ms/cm to 0.611 Ms/cm, reducing sugar content – from 78.56% to 80.7%, which meets quality standards. Generalization and systematization of data on the world beekeeping market and experimental determination of the physicochemical properties of honey and beekeeping products made it possible to obtain new data on the research topic for use in the beekeeping industry in Ukraine.

Keywords: *beekeeping, world market, market segmentation, ecological role, honey, physicochemical indicators.*

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1. Introduction

In [1], beekeeping is defined as a sectoral practice that involves raising honey bees for the purpose of collecting honey and other bee products, and also contributes to the creation of jobs and a stable income for rural communities. Beekeeping technologies are inexpensive, very simple, effective and convenient methods of harvesting natural resources, saving energy and restoring the environment, with profitable work for those who plan to raise honey bees. Beekeeping plays a key role in increasing crop yields through pollination [2]. It ensures ecological balance through pollination, increases crop yields, maintains biodiversity and provides environmentally friendly products and is an important component of sustainable development. It is also an economically sustainable business that supports rural communities. Added value and organic beekeeping open up new ways of generating income, so beekeeping can be considered as a component of sustainable development [3].

Beekeeping in Ukraine is of great importance, both for agriculture and for preserving biodiversity and ecological balance. It ensures the pollination of crops, which increases yields, and the production of valuable products, in particular honey, wax, pollen, propolis, etc. Bees also play an important role in supporting ecosystems, since the reproduction of many plant species depends on their pollination. According to the Department of Agro-Industrial Development and Land Relations (ADR and ZV) of the Donetsk Regional State Administration [4], there is a tendency to increase the export of Ukrainian honey, which indicates the potential of the industry.

The beekeeping industry in Ukraine is mainly developed in private farms, which produce 98% of the total volume of honey. This sector adds jobs to rural areas and supplies honey and other beekeeping products to the market, contributing to business development both in domestic and foreign markets through the possibility of export. An assessment of the current state of the industry shows that Ukraine is among the top ten world producers of honey in terms of production and is one of the leaders in terms of exports of beekeeping products. Domestic honey is mainly exported to the USA and EU countries.

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The main product of the beekeeping industry is honey. It is formed as a result of the combination of bees' own biologically active substances with plant nectar or the combination of secretions of living parts of plants and bee secretions and subsequent deposition, dehydration and storage in honeycombs until maturation [5]. The chemical composition of honey is very complex and depends primarily on its botanical origin. In general, this indicator of honey is one of the basic quality parameters and largely determines its cost [6]. Honey is rich in carbohydrates (glucose and fructose), so it is easily and quickly absorbed by the body, turning into energy [7]. This product is in great demand among the population, as it contains many vitamins, amino acids, macro- and microelements, phytoncides, flavonoids, essential oils, enzymes and other useful substances necessary for maintaining the vitality of the body [8, 9].

World honey production is 1.5 million tons per year, and Ukraine accounts for 5%. According to FAO, Ukraine ranks first in honey production among European countries (with a gross harvest of up to 75 thousand tons) and fourth after such world leaders as China (367 thousand tons), Turkey (81.4 thousand tons) and Argentina (81 thousand tons). In total, there are about 700 thousand people engaged in beekeeping and honey production in Ukraine – 1.5% of the country's population [10]. According to an analytical report [11], the average honey consumption per person per year is: Ukraine – about 0.8–1.2 kg, the USA – 0.76 kg, EU countries – 0.65 kg, China – 0.25 kg. The Resolution of the Cabinet of Ministers of Ukraine dated November 22, 2004 No. 1591 "On Approval of Nutrition Standards in Educational and Children's Health and Recreation Institutions" stipulates that the honey consumption rate should be about 2.5 kg per year.

The cited scientific sources [1–11] contain practically no data on the generalization and systematization of world beekeeping markets and its equipment. The literature contains only the results of studies of individual physicochemical indicators of honey quality and organoleptic and physicochemical properties of propolis, which require definition, clarification and organization.

For the further development of beekeeping in Ukraine, it is advisable to conduct a study of the world market of the industry, determine the ecological role of beekeeping and assess the physicochemical properties of honey.

For the further progress and development of the beekeeping industry, it is advisable to conduct a study of the world market of the industry, determine the ecological role of beekeeping and assess the physicochemical properties of honey.

Therefore, *the object of research* is the world beekeeping market, the ecological role and physicochemical properties of the quality of honey and beekeeping products.

The aim of research is to assess the world beekeeping market.

Research objectives:

– to generalize and systematize the results of research on the state, problems and prospects of the world beekeeping market;

– to determine the ecological role and assess the physicochemical properties of the quality of honey and products based on it.

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2. Materials and Methods

The following methods were used in the research:

– scientific methods: method of searching for data from literary sources and analytical reports on the topic under study; method of data analysis; method of systematization and classification;

– practical methods: study of physicochemical characteristics of honey (determination of mass fraction of water, diastase activity, electrical conductivity, content of reducing sugars, presence of starch).

The materials for the research were 4 samples of honey from different regions of Ukraine – Kyiv, Zhytomyr and Chernihiv regions and the Republic of Moldova.

3. Results and Discussion

3.1. State, problems and prospects of the global beekeeping market

3.1.1. General characteristics of the global beekeeping market

According to Cognitive Market Research, the volume of the global beekeeping market in 2024 amounted to 12.5 billion USD and is projected to grow at a CAGR of 6.0% from 2024 to 2031 [12]. According to Market Analysis Report, the global beekeeping market was valued at 9.31 billion USD in 2024 and is projected to grow to USD 11.78 billion in 2030 with a CAGR of 4.0% from 2025 to 2030 [13]. Data from analytical reports [14–16] confirm the global beekeeping market size and CAGR reported in [12].

Key findings on the global beekeeping market:

– North America held the largest market share with a revenue share of over 40% of global revenue and a market size of 5.0 billion USD in 2024, growing at a CAGR of 4.2% from 2024 to 2031;

– Europe accounted for over 30% of global revenue and a market size of 3.8 billion USD;

– Asia-Pacific accounted for about 23% of global revenue with a market size of 2.9 billion USD and a CAGR of 8.0%;

– Latin America had a market share of over 5% of global revenue with a market size of 6.3 billion USD and a CAGR of 5.4%;

– Middle East and Africa segment accounted for about 2% of market revenue (the region's market size was 2.5 billion USD with a CAGR of 5.7% (Fig. 1).

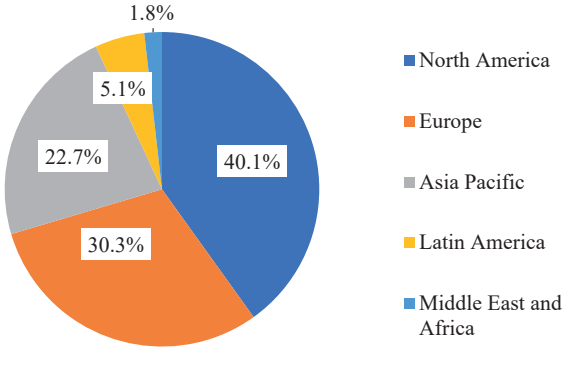

Fig. 1. Segmentation of the global beekeeping market by geographical regions (2024), % (based on data [12])

The driving forces and restraining factors of the market determined its dynamics. Based on the generalization of research results [1–3, 5–9] and analytical reports [12–17], it is possible to identify factors that stimulate the growth of the beekeeping market. First of all, this is the increased demand for natural and organic food additives with a sweet taste. The growth of the market is facilitated by the partial rejection of artificial food additives with a sweet taste. It is due to concerns about the possible side effects of synthetic additives and the possibility of considering honey and products based on it as a natural alternative to a healthier lifestyle. The growth of the market is also facilitated by the popularity of food additives with a sweet taste in the food industry and beverage production. The market is also positively impacted by the environmental benefits of organic farming without synthetic chemicals, using natural processes to maintain soil fertility and control pests.

Another important factor driving the market growth is the excellent natural healing properties of honey and its high demand in the

medical industry. Increased health awareness and preference for honey as a natural remedy over synthetic products for treating common diseases. The market growth is being fueled by the widespread use of honey in cosmetic and wellness products.

At the same time, there are obstacles to the growth of the beekeeping market. The use of pesticides and loss of habitat lead to a decline in the bee population, which in turn can lead to a decrease in honey production and agricultural yields.

According to Cognitive Market Research [12], North America dominates the beekeeping market. This dominance is primarily due to the high consumption of honey in the region and the introduction of modern beekeeping methods. The region's leadership position is also supported by the increased use of beeswax in eco-friendly packaging and cosmetics.

The Asia-Pacific region will witness the highest CAGR among geographical regions. This is due to the development of the agricultural sector and the expansion of the use of honey in traditional medicine and food products. The development of the region's cosmetics industry and the favorable climatic conditions for beekeeping and government programs to support it are also important.

3.1.2. Global beekeeping market segmentation by product type

In 2024, the honey segment dominated the market with the largest revenue share of 88.2% [13] (Fig. 2). Initially valued primarily for its medicinal properties, honey has become a major ingredient in the food and beverage industry. Its importance is due to the increased prevalence of consumption of natural sweeteners compared to artificial alternatives.

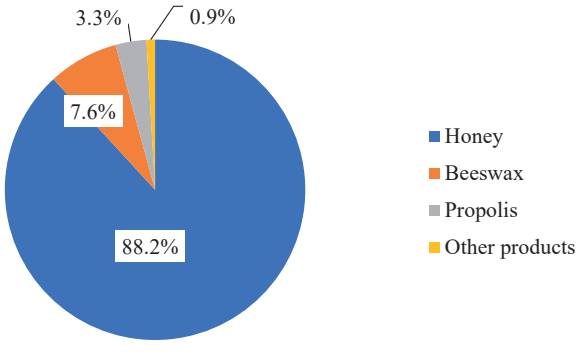

Fig. 2. Segmentation of the global beekeeping market by product type (2024), % (based on data [13])

The second largest segment in terms of revenue was the beeswax segment. This product is valued for its multifunctional properties:

– increased awareness of sustainable development and consumer transition to natural organic and chemically pure personal care products has increased the demand for beeswax;

– use in the cosmetic industry – acts as a natural emulsifier and thickener in products such as lip balms, creams and lotions;

– use in food packaging – provides environmental friendliness to food packaging;

– use in the pharmaceutical sector – is used in ointments and tablet coatings.

An important product of beekeeping is royal jelly. This product is gaining popularity in the health and wellness market due to its potential health benefits, including immune system support and energy enhancement. Its addition to health-oriented diets positions royal jelly as a valuable product in the beekeeping market.

Using data from the analytical report [14], the global beekeeping market can be segmented by product type, somewhat different from the analytical report [13], namely the beeswax, honey, and royal jelly segments (Fig. 3).

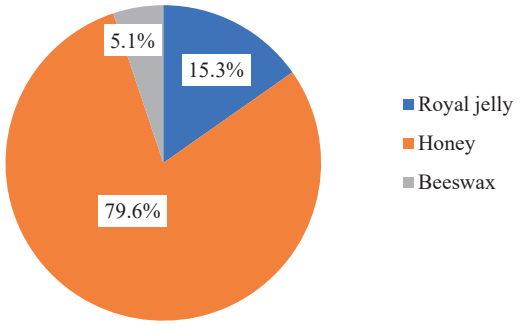

Fig. 3. Segmentation of the global beekeeping market by product type (2024), % (based on data [14])

The honey segment held the largest share of the global market in 2024 and is expected to grow at a faster pace in the next few years. Initially, the role of honey was limited to medicinal purposes, but over time it has become an integral part of the food and beverage industry. Moreover, the increased consumer demand for replacing artificial sweeteners with natural ones has also forced manufacturers to explore the main opportunities in the honey sector. Royal jelly is a new product that is used mainly in the production of food additives and cosmetics for personal hygiene.

Using data from the analytical report [15], segmentation of the global beekeeping market by product type can be carried out according to a larger number of segments: honey, beeswax, royal jelly, propolis and others. The honey segment, with a market revenue share of 58.4%, dominated in 2024 and is expected to grow at a CAGR of 4.1% through 2034 (Fig. 4).

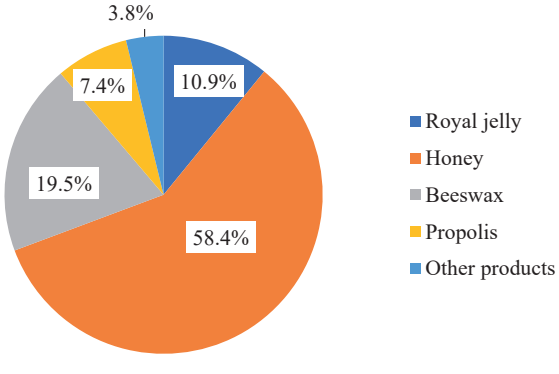

Fig. 4. Segmentation of the global beekeeping market by product type (2024), % (based on data [15])

It should be noted that the differences in the shares of segments (Fig. 2–4) are due to different segmentation taking into account different numbers of segments.

For reasons related to nutrition and medicine, consumers on a large scale prefer raw, organic and monofloral honey. In addition, the natural aroma of honey, as well as its antibacterial and antioxidant properties, increase its attractiveness to various segments of the population who care about their health.

The beeswax segment took the second position. This adaptable by-product in the beekeeping market is widely used in the production of candles, cosmetics and environmentally friendly packaging. Its natural origin and flexibility create expectations for environmentally conscious industries.

Known for its rich nutritional profile and hormone-regulating effects, royal jelly is widely used in food supplements, as well as anti-aging skin care products. Due to its limited production, it has a high price.

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Propolis has antimicrobial and anti-inflammatory properties. It is used to make throat sprays and tinctures, as well as natural remedies (alcoholic and aqueous tinctures, propolis ointments, honey-propolis mixtures, propolis milk/oil, natural propolis for various uses).

Together, the three by-products significantly expand the beekeeping market beyond honey, while responding to the increased need for health and well-being.

Using data from the analytical report [16], the global beekeeping market segmentation by product type can be carried out taking into account the live bees segment. This segment corresponds to the costs of a bee colony as a whole biological unit. It dominated the market with a revenue share of 42.1% in 2023. The honey segment had a market share of 30.8% (Fig. 5).

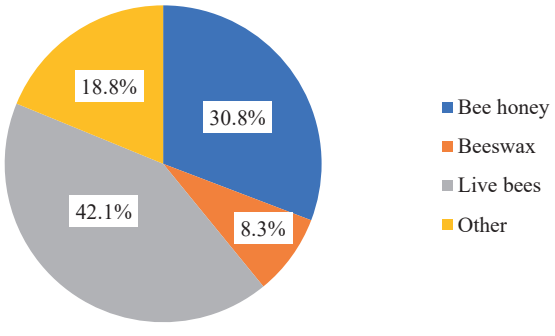

Fig. 5. Segmentation of the global beekeeping market by product type (2023), % (based on data [16])

3.1.3. Segmentation of the global beekeeping market by application

Data from the analytical report [17] allow to segment the global beekeeping market by application: food and beverages, agriculture, medicine, cosmetics, chemicals and paints, other industries. The leading positions in this segmentation were held by the following segments: food and beverages (market revenue share 39.7%), agriculture (22.1%) and medicine (18.6%) (Fig. 6).

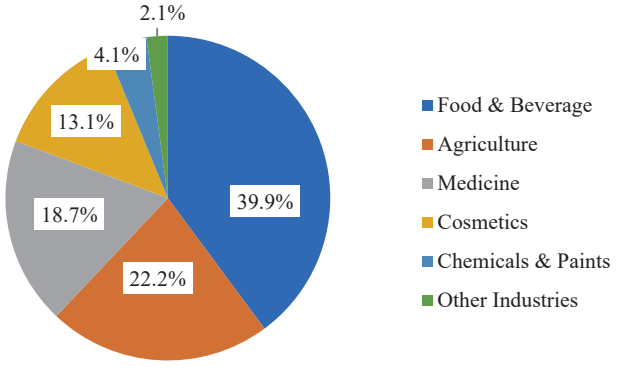

Fig. 6. Global beekeeping market segmentation by application (2024), % (based on data from [17])

The revenue shares of the cosmetics and chemicals and paints segments were 13.4% and 4.1%, respectively.

3.1.4. Global beekeeping market segmentation by end user

Food and beverages dominated the market with the largest revenue share of 43.5% in 2024 [13] (Fig. 7). As consumers become more health conscious, there is a noticeable shift from artificial sweeteners to natural alternatives, with honey being the preferred choice due to its rich taste and health benefits.

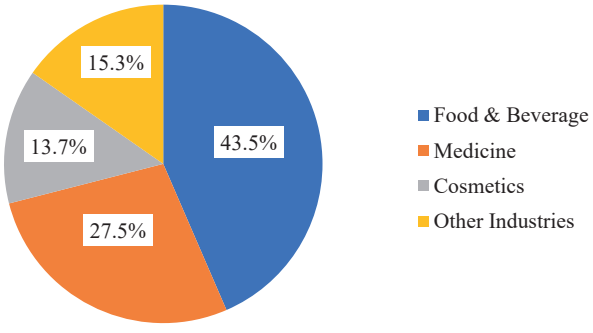

Fig. 7. Segmentation of the global beekeeping market by end user (2024), % (based on data [13])

According to the segmentation by end user, the medical industry segment was in second place in terms of revenue share. Beekeeping products are recognized for their therapeutic properties. For example, honey is used in medical dressings, royal jelly and propolis – to support immunity. The cosmetics industry took third place among the segments, largely due to the use of beeswax and royal jelly.

Using the data of the analytical report [15], the segmentation of the global beekeeping market by end user can be carried out by slightly different segments: food and beverages, pharmaceuticals, cosmetics and personal care, and others. The food and beverage segment exceeded 5.8 billion USD in 2024 and is expected to grow at a CAGR of 4.2% from 2025 to 2034. It dominated the market with a revenue share of 54.9% (Fig. 8).

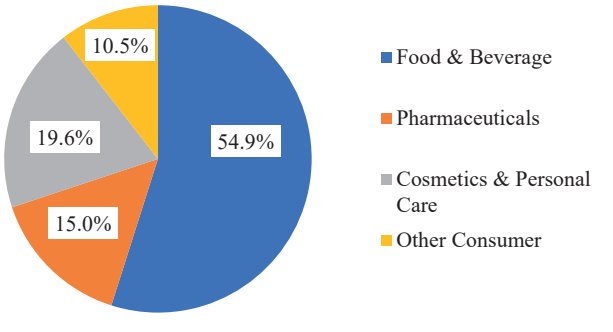

Fig. 8. Segmentation of the global beekeeping market by end user (2024), % (based on data from [15])

The beekeeping market is mainly fueled by the dominant food and beverage industry, which uses honey as a natural sweetener and flavoring.

The second position in the market belonged to the cosmetics and personal care products segment. Beeswax, honey and royal jelly are increasingly used in moisturizers, lip balms, face masks and anti-aging products due to their nourishing, protective and rejuvenating properties.

In the pharmaceutical industry, honey, propolis and royal jelly are ingredients of bee origin with antibacterial, anti-inflammatory and wound healing properties, which are used in cough syrups, lollipops, ointments and supplements. Their introduction into natural and traditional medicine ensures a constant demand.

In other sectors, the organic and natural approach to skin care products has led to an increase in the use of beekeeping-based ingredients, making these two sectors crucial for expanding market applications beyond food.

3.1.5. Beekeeping market segmentation by distribution channel

By distribution channel, the beekeeping market is segmented into online retail, supermarkets/hypermarkets, specialty stores, and direct sales.

The supermarkets/hypermarkets segment held a significant market share of 34.7% in 2024 [15]. Supermarkets and hypermarkets have the most developed distribution channels for beekeeping due to:

– easy accessibility, large shelves, and the ability to have a wide range of different beekeeping products;

– the ability to serve many consumers who value convenience of shopping, value for money and brand loyalty;

– a wide range of honeys of different origins, as well as local and international honeys, cosmetic and health products;

– advertising in supermarkets, product displays and loyalty programs;

– associations with certified organic and fair trade brands that encourage more consumers who care about health and the environment.

3.1.6. Distribution of funding depending on the areas of beekeeping development

Using the research data [18, 19], it is possible to determine the distribution of funding depending on the areas of beekeeping development. The leading areas were the treatment of Varroa with a share of funding of 29.9% and technical and educational support with a share of 27.5% (Fig. 9).

Prevention of Varroa is aimed at controlling the infection of bee colonies with an endemic parasite. Varroa is caused by a mite that weakens the immune system of bees, resulting in an increased incidence of secondary infections. Control of Varroa is largely achieved by reducing the parasite load on colonies. Varroa significantly reduces honey production in the EU, and the lack of treatment leads to the death of bee colonies.

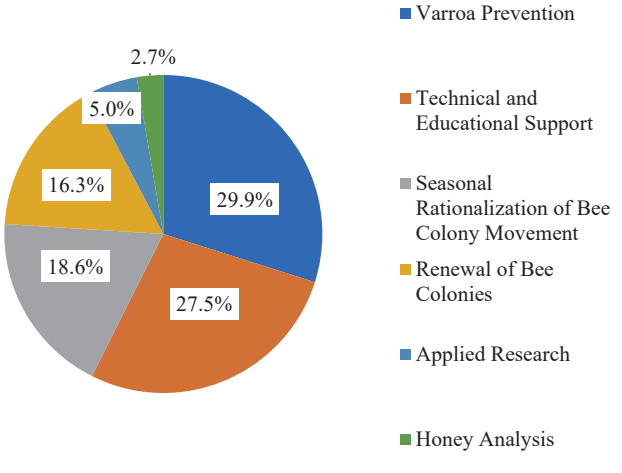

Fig. 9. Distribution of funding depending on the areas of beekeeping development (2020), % (based on data [18, 19])

Technical and educational support is aimed at increasing the efficiency of manufacturing and marketing of beekeeping products through the use of improved technological methods of production and the adoption of advanced practical experience. This area includes the organization of basic courses for new industry employees and advanced training for experienced beekeepers, as well as persons involved in industry management at higher levels of management. Such education is aimed at the adoption of advanced practical experience and modernization of the industry by switching to modern production.

The areas of rationalization of seasonal movement of bee colonies and renewal of bee colonies had funding shares of 18.6% and 16.3%, respectively. Rationalization of seasonal movement of bee colonies is aimed at assisting in managing the movement of bees across the EU. This rationalization also involves providing sites for mobile apiaries during the flowering period of honey plants, organizing the provision of a sufficient number of bee colonies for pollination in all EU Member States. The renewal of a bee colony can occur naturally, or artificially, by repopulating with a new queen. This is necessary to maintain strength and productivity, improve the genetic composition of the colony.

The direction of financing applied research is aimed at implementing the results of research projects to improve the technology of obtaining and quality of honey, and the direction of honey analysis is aimed at determining the quality and naturalness of honey using organoleptic and physicochemical methods.

3.1.7. General characteristics of the global beekeeping equipment market

The volume of the beekeeping equipment market was estimated at 1.83 billion USD in 2024. According to forecasts, the market will grow from 1.91 billion USD in 2025 to 2.86 billion USD by 2034. The market's GPA is expected to be around 4.6% during the forecast period (2025–2034) [20].

Using the data from the analytical report [20], the market can be segmented into the following segments of beekeeping equipment: hives, protective clothing, honey extraction, smokers, and beehive tools. The hive segment dominated in 2023 with a revenue share of 48.1% (Fig. 10) due to the development of beekeeping in developing countries and the improvement of the material and technical base and technological processes in the industry.

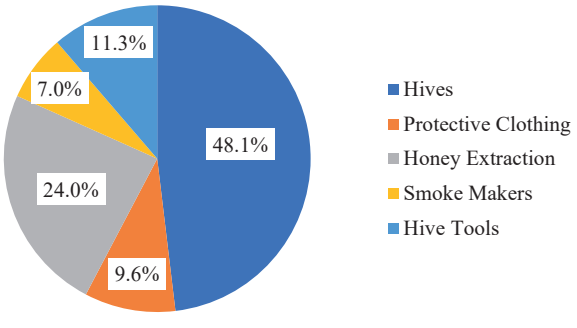

Fig. 10. Segmentation of the global beekeeping equipment market by equipment type (2023), % (based on data from [20])

Technological advances determine the second position of the honey pumping segment. The beehive tools segment is forecast to grow moderately due to investment in multifunctional tools. The protective clothing segment is expected to show steady growth due to increased awareness among industry workers and innovations in materials and technologies for manufacturing protective clothing. The smoke makers segment is forecast to grow due to increased popularity and image of beekeeping.

Due to the numerous market "players" and dislocations of the beekeeping industry, the equipment market is highly competitive. The competitive landscape of the market will be determined by research and development activities and strategic partnerships in the near future.

Regional segmentation of the beekeeping equipment market provides valuable information about the geographical distribution of the market and growth patterns. According to the segmentation of the equipment market by geographical regions, the Asia-Pacific segment held the leading position with a revenue share of 33.1% (Fig. 11). The revenue shares of the European region and North America were 31.8% and 31.4%, respectively. The Asia-Pacific region is projected to experience the largest growth due to the introduction of modern beekeeping technologies.

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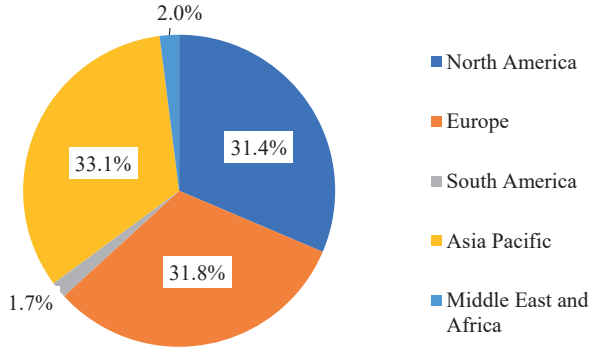

Fig. 11. Segmentation of the global beekeeping equipment market by geographical region (2023), % (based on data [20])

Urbanization processes and changes in the food industry contribute to the further development of the market in South America and the Middle East and Africa.

3.1.8. Trends in the development of the global beekeeping market

The results of research [1–3, 5–9] and analytical reports [12–17] allow to identify the main trends in market development. The North American beekeeping market is characterized by rapid growth due to a significant increase in consumer demand for natural products, consumer awareness and significant government initiatives.

The beekeeping market in the USA is characterized by a well-established ecosystem of commercial beekeepers, amateurs and value-added producers. Growing consumer awareness and environmental preferences determine the future prospects of the market. The focus on natural sweeteners instead of refined sugar and artificial sweeteners in the food sector increases the demand for honey in the Asia-Pacific region.

The world's largest honey producer is China. It accounts for approximately 50.5% of the world's honey production. The country's leading position is due to the popularity of beekeeping and climatic conditions.

In Europe, the development of beekeeping is associated with the important role of bees in biodiversity and agriculture. European governments are actively funding beekeeping practices and educational programs, which contributes to the growth of the beekeeping market.

3.1.9. Ecological role of beekeeping

Beekeeping is of great importance in protecting ecological systems. Pollination contributes to plant reproduction, biodiversity conservation, and food security. Using the results of research [21–23], it is possible to identify the main aspects of the ecological role of beekeeping:

– plant pollination;
– biodiversity conservation;
– support of food chains;
– importance of beekeeping products for humans (nutrition, treatment, use in various industries);
– fulfilling the indicator role of assessing the ecological state;
– economic importance for the development of agriculture and the food industry.

3.2. Assessment of physicochemical properties of honey quality and products based on it

3.2.1. Main physicochemical indicators of honey quality

Physicochemical properties (water content, sugars, acidity, diastase activity, presence of pollen and other substances) determine the quality of honey and affect the taste, aroma, color, consistency and shelf life of honey. A summary of studies [24–27] allows to identify the main physicochemical indicators of honey quality: moisture (water content); sugar content; free acidity; diastase activity; electrical conductivity; mineral content (ash); presence of pollen; color, taste, smell, consistency. Important aspects of honey quality include: maturity (sufficient sugar content and minimum water); absence of impurities; absence of heating. (Heating honey can lead to loss of beneficial properties and significant deterioration in quality).

3.2.2. Determination of honey moisture

Honey moisture is one of the indicators of its quality. It is determined by the percentage of water in honey and is regulated in DSTU 4497:2005 [28]. Honey moisture directly depends on its maturity, as well as on storage conditions. An unripe product has high humidity (above 20%), so it is unsuitable for long-term storage and spoils quickly. Mature honey contains an average of 18–20% water. Excess water can dramatically worsen the beneficial properties and shelf life of honey. The fermentation process turns honey into a foamy mass.

The determination of the mass fraction of water was carried out according to the method [28, 29] using an Abbe RHF-30ATC refractometer, a water bath, and a mercury laboratory thermometer up to 100°C according to GOST 28498. Liquid honey was used for the test, which was obtained by heating crystallized honey to a temperature of 60°C. The refractive index of cooled liquid honey was measured with a refractometer.

The mass fraction of water in the studied honey samples ranged from 17.5% to 19.8% (Table 1), which corresponds to the standards of DSTU 4497:2005 [28].

Table 1

Results of studies of honey quality indicators from different regions

Region name	Indicator			
	Mass fraction of water, %	Diastase number, Gotpe units	Electrical conductivity, mS/cm	Mass fraction of reducing sugars, %
Kyiv region	17.5	18.34	0.359	78.6
Zhytomyr region	17.9	15.54	0.349	80.5
Chernihiv region	19.8	34.35	0.476	80.5
Moldova	19.5	38.59	0.611	80.7

3.2.3. Determination of diastase activity of honey

The diastase number depends on the amount of enzymes that the bee secretes when processing nectar into honey, and on the biological origin of the nectar. The enzymatic activity of honey decreases after its long-term storage or heating, so this parameter can be used to characterize fresh honey. The Gothe diastase number is an extremely valuable indicator of honey quality, as it allows to assess whether the honey under study is a natural product. This enzyme is responsible for the breakdown of starch and other polysaccharides into disaccharides, since diastase interacts with other enzymes. It is an indicator of the total amount of enzymes in honey. In addition, this enzyme is one of the most stable, which allows it to be used as an indicator of the content of other enzymes [30].

The determination of the diastase number of honey samples was carried out according to the method [28, 29] using the necessary basic equipment: spectrophotometer 721 EU (Clandjones, China); pH meter PHS-3C (Kelilong Electron, China). The optical density of the samples was measured on a photoelectrocolorimeter at a wavelength of 590 nm against water in a 10 mm thick cuvette. The final result was taken as the arithmetic mean of the results of two tests. The permissible difference between the two tests should not exceed 0.5 Gothe units. According to the results of the studies, the diastase number ranges from 15.54 to 38.59 Gothe units (Table 1).

3.2.4. Measurement of the electrical conductivity of honey

Electrical conductivity is a parameter included in new international standards and makes it possible to determine the differences between honey dew and flower honey [31]. The electrical conductivity of flower honey is lower than that of honeydew, so this parameter can be used as a criterion if necessary to distinguish paddy honey from flower honey [32, 33]. In general, Ukrainian paddy honeys have an electrical conductivity of 0.45–1.102 mS/cm with an average value of 0.9 ± 0.2 mS/cm [26]. As for the indicator of the amount of reducing sugars, they characterize honey in terms of its maturity and quality. They can be one of the indicators of the biological origin of honey. An increased sucrose content compared to the norms indicates that the honey is either adulterated or obtained by bees that were fed sugar syrup.

The electrical conductivity of honey samples was measured according to the method [28, 29] and at a temperature of 200 C using the following basic equipment: EZODO CTS-406 conductometer (GOnDO Electronic, Ltd., Taiwan) with a remote electrode and a temperature sensor; a conductometric cup with a platinum double electrode (immersion). The arithmetic mean of the results of two tests was taken as the final result. The permissible difference between the two tests should not exceed 0.05 mS/cm. According to the results of the studies, the electrical conductivity of 4 honey samples from different regions of Ukraine ranged from 0.349 MS/cm to 0.611 MS/cm (Table 1).

3.2.5. Determination of reducing sugars in honey

The determination of reducing sugars is of great importance for assessing the quality of honey:

– the content of reducing sugars in honey is one of the important indicators of its quality and maturity;

– an increase in the content of reducing sugars (glucose and fructose) indicates that the honey is maturing and the bees have converted most of the sucrose into fructose and glucose;

– the amount of reducing sugars can also affect the properties of honey, such as crystallization, color and taste.

Several methods are used to determine the content of reducing sugars in honey, in particular, the Fehling method and iodometric titration, as well as methods based on optical density determination. These methods allow quantitatively determining the content of glucose and fructose, which are the main reducing sugars in honey. Fehling's method and iodometric titration are based on the ability of reducing sugars to reduce cupric ions in Fehling's solution [34, 35]. To perform the reaction with sugars, honey is dissolved in water, Fehling's solution (a mixture of copper(II) sulfate, sodium-potassium tartrate, and sodium hydroxide solutions) is added, and heated.

The reaction results in the formation of a precipitate of cupric(II) oxide, the amount of which is determined by iodometric titration. The content of reducing sugars in the 4 honey samples studied ranged from 78.56% to 80.7% (Table 1) and meets the standards [30, 34, 35].

3.2.6. Testing honey for starch

Flour and starch are added to honey to create the appearance of crystallization, which usually indicates its naturalness. Two methods were used to detect flour or starch impurities [36, 37]:

– interaction of honey solution with Lugol solution – the appearance of a blue color indicates flour or starch impurities in honey;

– interaction of honey diluted with distilled water with 5% alcohol solution of iodine – in the presence of an impurity, the solution turns blue.

In all the honey samples examined, no adulteration (presence of starch) was detected.

3.2.7. Study of organoleptic and physicochemical parameters of propolis

Propolis (bee glue) is a resinous substance that bees collect from tree buds, bark and other plants. It is a multicomponent formation that contains resins, wax, essential oils, flavonoids, vitamins and other biologically active compounds. Such a mixture causes antibacterial, antiviral and antioxidant properties, anti-inflammatory, analgesic and immunomodulatory effects [38, 39]. Propolis is widely used in folk and traditional medicine, as well as in cosmetology.

Propolis is a unique natural product, which includes more than 800 substances. It has a specific pleasant smell of birch or poplar buds, vanillin, when burning - incense, and tastes bitter-spicy [40, 41]. Propolis contains a range of valuable biologically active components, therefore it has a diverse pharmacological activity. A significant part of the components of propolis are substances of phenolic nature (not less than 25%) – flavones (chrysin, tectochrysin), flavonols (galangin, isalpinin, rhamnocitrin), phenolcarboxylic acids, oxycoumarin, quercetin and its derivatives, polyphenols [40–42].

Propolis from different regions of Ukraine was studied for compliance with the requirements of quality standards. The research was conducted in accordance with the technical conditions of DSTU 4662-2006 [43]. 19 samples of propolis from different regions of Ukraine were studied. At the first stage, the organoleptic properties of propolis were analyzed. It has a color from dark green to yellow-brown shades and a pronounced resinous (mixture of odors of honey, pine needles, poplar) odor.

Organoleptic quality indicators are important in assessing the properties of food products. The obtained results of the assessment of the quality of propolis by organoleptic and physicochemical indicators are summarized in Tables 2 and 3. They indicate that propolis by organoleptic and physicochemical indicators fully meets the technical requirements.

Table 2

Organoleptic indicators of propolis

Indicator name	Standard DSTU 4662-2006	Research
Appearance	Clumps, crumbs or briquettes	Bricks, lumps and crumbs
Color	Dark green, brown, greenish-brown, brown, gray with a greenish, yellow or brown tint	From dark green to brown with greenish and yellow shades
Odor	Resinous (a mixture of smells of honey, pine needles, poplar)	Characteristic – resinous
Taste	Bitter, slightly burning	Bitter, slightly burning
Structure	Dense, heterogeneous at the break	Dense, heterogeneous at the break

Table 3

Physico-chemical quality indicators of propolis

Statistical indicator	Density at a temperature of 20°C	Mass fraction of wax, %, not more than	Mass fraction of mechanical impurities, %, not more than	Mass fraction of flavonoid compounds, %, not less than
$M \pm m$	1.16 ± 0.01	9.25 ± 0.70	9.34 ± 0.68	39.41 ± 2.53
ð	0.01	2.89	2.82	10.44
n	17	17	17	17
DSTU requirements	1.120–1.187	15	15	25

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The high content of flavonoid compounds in 17 propolis samples from different regions of Ukraine meets the technical requirements [43] and is on average 39.41 ± 2.53%. Such a content of flavonoid compounds in the studied samples indicates a high biological activity of propolis from different regions of Ukraine, determining the antibacterial and other pharmacotherapeutic properties of propolis.

Studies of propolis samples for the content of the mass fraction of mechanical impurities from different regions of Ukraine showed that out of 19 samples received by the laboratory, 17 met the requirements of DSTU 4662-2006 [43] with an average value of 9.34 ± 0.68%.

It should also be noted that in all propolis samples the content of the mass fraction of wax was not more than the permissible norms and is on average 9.25 ± 0.70%.

3.3. Discussion of beekeeping problems in Ukraine

There are several urgent problems in the beekeeping sector that require immediate solutions [23, 44]:

– lack of effective state financial support for the industry;
– reduction of areas under crops that are sources of pollen for bees;
– limited material base of apiaries and low efficiency of their activities due to outdated industrial technologies;
– reduction of the scale of crops of entomophilous agricultural plants and insufficient use of bee pollination;
– deterioration of the ecological state of the natural environment and violation of technological requirements for the treatment of entomophilous agricultural plants with pesticides and toxic chemicals and as a result – mass poisoning of bees;
– insufficient veterinary support, which leads to the uncontrolled spread of bee diseases;
– the need to improve the technological culture of production, processing and packaging;
– lack of the necessary set of legislation on the production and quality of the industry's products and, as a result, difficulties in realizing the industry's export potential;
– reduction in the price of honey when exported.

Thus, taking into account the developed agriculture and horticulture, the beekeeping complex of Ukraine has prospects for increasing the yield of grain, technical, fruit and berry and vegetable crops. Improving the efficiency of beekeeping is possible by increasing the labor productivity of employees of bee farms and specialized beekeeping farms. This can be achieved through the introduction of scientific progress, automation of technological processes and compliance with optimal conditions for honey collection and preservation of Ukrainian endemic bee breeds [23, 44].

An assessment of the current state of the beekeeping industry of Ukraine [23] shows that the country is among the five major producers of honey in terms of gross production and per capita consumption of this product. In the context of increasing integration processes and international competition, Ukraine can enter the world beekeeping markets with high-quality products. And beekeeping products can potentially become one of the main export-oriented industries of Ukraine, since the world demand for this product is not satisfied. Ukrainian bee products are of high quality and, provided that they have the appropriate level of certification, can compete adequately in international markets.

Practical significance. The results obtained in the course of research can be used for a comparative assessment of the state of the Ukrainian beekeeping market, the physicochemical characteristics of honey quality, and the identification of market strengths and weaknesses.

Taking into account factors that positively and negatively affect the world market will enable better integration of the Ukrainian market into the world market. Research into beekeeping markets in different countries of the world can be useful for the development of the domestic market.

Research limitations. The research of the physicochemical properties of honey and products based on it was carried out mainly only for products obtained by Ukrainian producers.

Impact of martial law conditions. Under martial law conditions, significant disruptions in the supply chains of beekeeping products and equipment are observed, which leads to a slowdown in the pace of market development.

Prospects for further research. Using approaches and methods for assessing the global beekeeping market, these results can be used in the future for the further development of the Ukrainian market.

4. Conclusions

1. Beekeeping is of great ecological and economic importance for the development of humanity and the environment. It is shown that the key factors stimulating the growth of the beekeeping market are the increased demand for organic and natural sweeteners and increased awareness of the medicinal properties of honey. Significant challenges to its development include the reduction of the bee population. According to the segmentation of the global beekeeping market in 2024, the following segments dominated: by geographical region – North America (with a revenue share of 40.1% of the global market), by product type – honey (88.2%), by application – food and beverages (39.9%), by end user – food industry (43.5%), by sales channel – supermarket/hypermarket segment (34.7%); by funding distribution – prevention of bee diseases (29.9%).

2. The physicochemical quality indicators of honey in samples from different regions of Ukraine (Kyiv region, Zhytomyr region, Chernihiv region) and the Republic of Moldova were studied. The mass fraction of water in the studied honey samples ranged from 17.5% to 19.8%, the diastase number – from 15.54 to 38.59 Gothe units, electrical conductivity – from 0.349 MS/cm to 0.611 MS/cm, the content of reducing sugars – from 78.56% to 80.7%. The obtained indicators meet quality standards.

Conflict of interest

The authors declare that they have no conflict of interest regarding this research, including financial, personal, authorship or other nature, which could affect the research and its results presented in this article.

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The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies in creating the presented work.

Authors' contributions

Viktor Malyshev: Conceptualization, Methodology, Data curation, Supervision; ***Liudmila Lopukh:*** Investigation, Resources, Writing – original draft; ***Yuliia Yatsiv:*** Investigation, Resources, Writing – original draft; ***Angelina Gab:*** Validation, Writing – original draft, Writing – review and editing, Visualization; ***Dmytro Shakhnin:*** Formal analysis, Writing – review and editing, Visualization.

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