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STUDY OF THE BOTANICAL ORIGIN OF BEE HONEY OF UKRAINE

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Abstract. *The purpose of this study was to analyze Ukrainian bee honey according to organoleptic characteristics and species composition of pollen grains, to establish their origin, species and botanical homogeneity. Methods. The study of organoleptic indicators and pollen composition of bee honey was carried out using the methods specified in DSTU 4497:2005 "Natural honey. Technical conditions". Botanical homogeneity, i.e. monofloral or polyfloral, was determined in accordance with the Order on the Approval of the Requirements for Honey (MAPPU Order No. 330 on the Approval of the Requirements for Honey, 2019). The results. 156 samples of bee honey obtained from different regions of Ukraine were analyzed. Compliance with the requirements for the quality of natural honey according to organoleptic indicators has been established. The variety of botanical origin has been specified. The study of the species composition of pollen grains proved monofloral in 33 honey samples and polyfloral in 121. In addition, according to the results of the tests, 2 samples were classified as honeydew honey. Conclusions. Our tests have confirmed the unique pollen composition of each individual bee honey, on which the organoleptic properties depend. The pollen analysis of bee honey can be used to determine not only the type of raw material, botanical composition of honey, but also its geographical origin. Given the complexity of the microscopic method of studying the species composition of pollen grains of bee honey, there is a need to find new research methods.*

Keywords: bee honey, organoleptic characteristics, pollen analysis, dominant pollen grains, honey origin

Introduction. The geographical location of Ukraine creates quite favorable conditions for the development of beekeeping. Since ancient times, our ancestors have used bee honey not only as a food product, but also as a medicinal product (Cernak, 2012; Alvarez-Suarez, 2019). And the presence of the most diverse species composition of natural flora and cultivated honey plants provides a significant number of types of honey.

Flower honey is formed by processing plant nectar by bees. It is classified as monofloral and polyfloral. Monofloral honey is obtained when bees collect nectar mainly from one type of plant. The name of such honey depends on the type of plant from which the nectar is taken. Thus, acacia, linden, buckwheat, heather, lingonberry, raspberry, clover honey, citrus honey are distinguished (Order of the Ministry of Agriculture, Food and Rural Affairs No. 330 On Approval of Requirements for Honey, 2019).

Most often, bees collect a mixture of nectars from several honey plants growing near the apiary. Polyfloral honey is obtained from the collected nectar in the absence of a dominant honey plant and is named after the areas where the main honey plants grow - steppe, field, meadow, mountain, or by region - Ukrainian, Bashkir, Far Eastern.

In case of reduction or cessation of nectar secretion in arid climatic conditions, bees begin to collect honeydew - a sweet liquid secreted by coniferous and broad-leaved trees, shrubs, grasses. As well as insects of the order Hemiptera, which suck plant sap. Honeydew

honey is distinguished by the names of the plants from which the honeydew is collected: from linden, spruce, pine, larch, oak, maple, plum (Bogdanov, 2004; Escuredo, 2013; Bentabol Manzanares, 2011; Belay, 2015; Seraglio, 2019).

In order to determine the botanical origin of bee honey, analysis of the species composition of pollen grains is most often used (Martins, 2011; Atanassov, 2012; Kocsis, 2022).

Such tests are important not only to determine the type of honey and the presence of dominant pollen grains. Today, the need to provide information to consumers to prevent food allergies is of particular importance. In accordance with the Law of Ukraine "On Information for Consumers" and the Order of the Ministry of Agrarian Policy and Food of Ukraine "On Approval of Requirements for Honey", consumers have the right to detailed information on the type, composition, place of collection and other characteristics of honey that affect its nutritional and biological value.

In addition, by analyzing the pollen composition of bee honey, it is possible to determine its regional origin (Moraes, 2019; Paredes, 2019; Adams-Groom, 2019; Fechner, 2020).

Methods and materials. During the 2021 honey collection season, 156 samples of bee honey obtained from apiaries in 21 regions of Ukraine were tested. The study of organoleptic indicators, as well as the species composition of pollen grains of honey, was carried out in accordance with DSTU 4497:2005 "Natural honey. Technical conditions" (DSTU 4497:2005, 2007). These tests were conducted at the State Research Institute for Laboratory Diagnostics and Veterinary and Sanitary Expertise in conjunction with the Department of Animal and Food Hygiene named after Professor A.K. Skorokhodko, National University of Life and Environmental Sciences of Ukraine.

Among the organoleptic indicators, color, consistency, taste and aroma were analyzed. The pollen composition of bee honey was determined by microscopic methods, establishing the morphological features of pollen grains of honey plants and identifying them using the International Palinological Database of Pollen Grains (PalDat) and the Atlas of Honey Plants (PalDat; Bondarchuk, 2011). 200 pollen grains were counted under a microscope and their species affiliation was recorded. The number of pollen grains of each species was expressed in percentages. The relative number of pollen grains determined the presence of the dominant pollen and the botanical origin of bee honey.

Results. The most common types of bee honey for Ukraine were tested. Among the floral honeys are monofloral honeys: from acacia, buckwheat, linden, rapeseed, sunflower and polyfloral - various herbs, as well as paddy honey. Each of them had a unique color, taste, aroma and consistency (Table 1).

The color of different varieties of honey varies from colorless to dark brown and even black and depends on many factors.

Acacia honey ranged in color from colorless to light yellow and was transparent. Buckwheat honey ranged from amber to dark brown. Linden honey had a characteristic amber color, and rapeseed honey was white with a light yellow or caramel tint. The color of Flower honey was light amber and amber. Sunflower honey was characterized by a peculiar golden yellow color, and honeydew honey was dark brown.

The consistency of honey samples correlated with the degree of crystallization. For example, freshly extracted honey was liquid or slightly viscous.

Most honey varieties undergo crystallization during storage and change their original consistency to a very viscous and even dense one due to the transformation of dissolved sugar into a solid. At the same time, the size of the crystals varies depending on the botanical origin of the honey. There is coarse-grained crystallization, fine-grained and lard-like - when the crystals are not visible to the naked eye.

As already mentioned, the consistency of acacia honey is liquid. During the tests, we observed slow crystallization by turning into a fine-grained mass in 2 samples of acacia honey only after 6 months and in 1 sample after 10 months.

Buckwheat honey has a viscous consistency, the crystallization of this honey began 2–3 months after pumping and it acquired a thick coarse-grained consistency.

Most flower honeys have a viscous consistency. Yes, the consistency of fresh linden honey was also viscous, after 3–4 months the crystallization process began and it became thick fine-grained.

Rapeseed honey was characterized by a viscous consistency at the beginning and quite quickly acquired a homogeneous creamy consistency, undergoing crystallization. In general, rapeseed honey is characterized by very rapid crystallization, which occurs in 7–15 days, since the ratio of glucose to fructose in it, as well as in sunflower honey, is quite high. The consistency of sunflower honey samples was dense, since it crystallizes quickly with the formation of specific large crystals and small lumps.

Table 1

Results of organoleptic analysis of honey

Types of honey	Color	Consistency	Aroma	Taste
Acacia Honey	Water white – extra white, transparent	Syrup-like	Delicate, slightly pronounced aroma with floral notes	Delicate, mild taste, reminiscent of sweet vanilla
Buckwheat Honey	Amber– Dark amber	Very viscous, coarse-grained	Characteristic aroma reminiscent of the smell of buckwheat flowers	Tart, burning, moderately bitter, which is typical for this type of honey.
Linden honey	Amber	Viscous, fine-grained	Persistent, rich, has the smell of linden flowers, sometimes with notes of mint	Tart, slightly bitter
Rapeseed honey	White with a light yellow or caramel tint	Homogeneous creamy	Rich pleasant	Sweet, slightly sugary
Flower honey	Light amber – amber	Viscous, medium to coarse grain	Subtle, pleasant	Rich flavor with a light floral aftertaste
Sunflower honey	Golden yellow	Dense with large crystals and small lumps	Floral with a pollen scent	Light, sweet
Honeydew honey	Dark amber	Viscous	Weak or no aroma	Sweet with a hint of bitterness, but without the taste characteristic of nectar honey

It should be emphasized that the organoleptic qualities of honey from various herbs are unpredictable, including its difficult-to-predict crystallization process. Experimental samples of

honey from various herbs were viscous with a grain size from medium to large. The crystallization process took 3–5 months.

Honeydew honey had a characteristic by stickiness and viscosity. No crystallization was observed during the test period. It should be noted that in general, paddy honeys are difficult to crystallize.

It is worth noting that the quality of honey and its chemical composition do not change during natural crystallization.

The taste and flavor of honey varies depending on the type of flowering plants from which the bees have taken nectar. These characteristics are due to the presence of organic acids and aromatic substances, represented mainly by essential oils. Freshly pumped honey is the most flavorful. Minerals also contribute to the flavor of honey. The high mineral content in honeydew honey gives it a salty taste. Mineral elements also reduce the acidity of honey, which slightly changes its flavor.

Acacia honey samples had a subtle, faint aroma with floral notes. The taste was delicate, soft, reminiscent of sweet vanilla.

Buckwheat honey was distinguished by a characteristic aroma reminiscent of the smell of flowers and a typical for this type of honey tart, burning, moderately bitter taste

Linden honey was characterized by a persistent rich smell of linden flowers, sometimes with notes of mint and tart, slightly bitter.

Rapeseed honey, which was subject to analysis, had a rich pleasant aroma, sweet, somewhat cloying taste.

The aroma of sunflower honey is floral with a pollen tinge. The taste is light, sweet.

The taste and aroma of honey from different flowers depended on the dominant flora in a particular region of Ukraine and the period of nectar collection. It had a rich taste with a light floral aftertaste, as well as fruity, herbal notes. The aroma of this honey is delicate, pleasant.

The aroma of honeydew honey was absent. The taste is sweet with bitterness, but not typical of nectar honey.

According to these results, it can be stated that the analyzed samples of natural honey meet the organoleptic requirements for its quality.

In order to confirm the botanical origin of honey, we determined the species composition of pollen grains. The basic method for studying the botanical origin of honey is microscopic. It is most often used in Ukraine.

The type of pollen was determined by its morphological features. Pollen grains of different honey plants have a specific shape, color and size. Their shape can be round, triangular, polygonal, oval, etc., and the surface is smooth, covered with spines, pores, furrows. In addition, pollen grains can be simple or complex, that is, consist of several cells. The sizes of pollen grains within a species can vary, while the shape and structure of their surface are stable for each species (Hnatyuk, 2013).

International standards for honey quality criteria are defined in the European Directive and the Codex Alimentarius (Ohe, 2000). Depending on the proportion of pollen in the total spectrum of pollen grains, the International Commission on Bee Botany classifies it into primary (more than 45%), secondary (16–45%) and individual inclusions (less than 16%). Pollen grains in quantities up to 1% are not counted, but their presence is noted. It is also necessary to distinguish another type of pollen – unknown pollen. Its amount affects the accuracy of the results obtained.

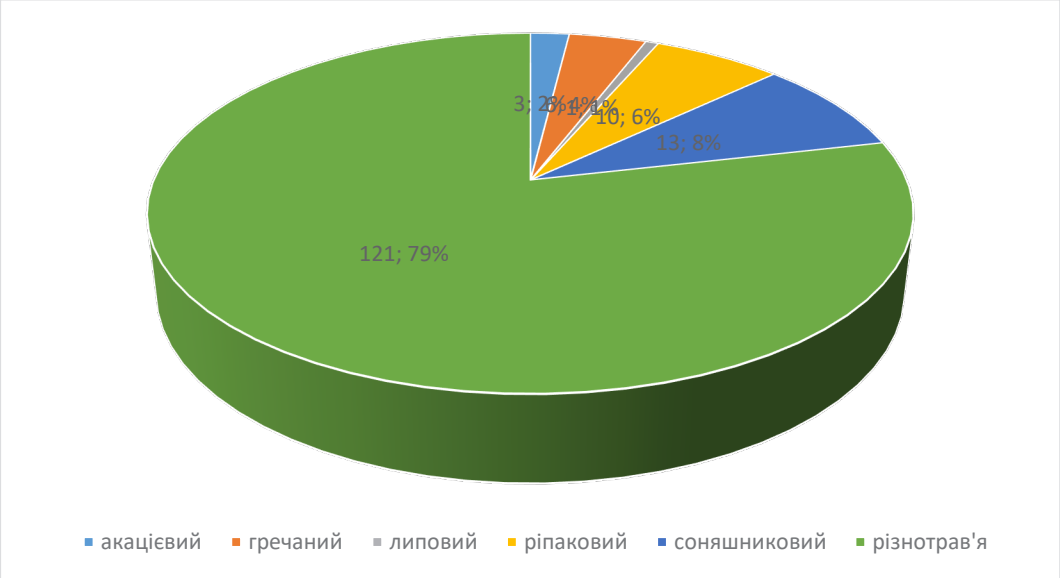
During the analysis of the pollen composition of floral honey, we established the presence of dominant pollen, which is an important criterion for determining the monofloral nature of honey. Each individual sample of floral honey includes a large number of pollen species. But it can be considered monofloral if pollen grains of one plant species dominate in an amount of at least 30% for all honeys. In acacia and linden honey, this indicator is set at a level of at least 20% (Order of the Ministry of Agriculture and Rural Development No. 330 On

Approval of Requirements for Honey, 2019). If we take into account the requirements of Council Directive 2001/110/EC, then at least 10% of the total number of pollen grains. Polyfloral flower (nectar) honey contained pollen grains of several plant species in an amount of less than 30% for all types of honey, and for acacia and linden honey - less than 20% (Order of the Ministry of Agriculture and Rural Development No. 330 On Approval of Requirements for Honey, 2019).

Pollen analysis confirmed the monofloral nature of 33 honey samples and the polyfloral nature of 121 samples. Among monofloral honeys, 3 samples of acacia honey, 6 – buckwheat, 1 – linden, 10 samples of rapeseed and 13 – sunflower were studied. Polyfloral honey is represented by various herbs. The total number of flower honey samples is 154 (Fig. 1).

The studied samples come from different regions of Ukraine. The ratio of dominant pollen grains in the analyzed flower honey is presented in Table 2.

Acacia honey was collected in Cherkasy region - 2 samples and Zakarpattia region - 1 sample. The relative number of grains of the dominant pollen (*Robinia pseudoacacia*) was set at 23-31%, which meets the requirements for monofloral honey of this botanical origin. In two samples of acacia honey from Cherkasy region, in addition to acacia pollen in the amount of 23 and 28%, pollen grains of such plants as white clover (*Trifolium repens*) were identified at the level of 14 and 8%, respectively, common rape (*Barbarea vulgaris*) - 10 and 7%, sowing alfalfa (*Medicago sativa*) - 3 and 7%, medicinal lungwort (*Pulmonaria officinalis*) - 6 and 4%, common bruise (*Echium vulgare*) - 5 and 9%, elderberry (*Sambucus nigra*) - 5 and 3%. Some of the pollen grains were present in one of the samples studied. These are pollen of rapeseed (*Brassica napus*) in the amount of 3%, raspberry (*Rubus idaeus*) - 4%, domestic apple tree (*Malus domestica*) - 3%, viburnum (*Viburnum opulus*) - 5%, and medicinal dandelion (*Taraxacum officinale*) - 8%, bush amorpha (*Amorpha fruticosa*) - 2%, white mustard (*Sinapis alba*) - 6%, common pumpkin (*Cucurbita pepo*) - 9%, common cucumber (*Cucumis sativus*) - 2%. This type of honey contains pollen from plants that bloom in different periods of honey harvesting. This includes rape and apple pollen.



Acacia (3) Buckwheat (6) Linden (1) Rapeseed (10) Sunflower (13) Polyfloral (121)

Fig. 1. The range of the number of honey samples of different types tested

Acacia honey of the Zakarpattia region contained 31% acacia pollen grains, Ivan-tea (*Chamaenerion*) –12%, raspberry (*Rubus idaeus*) – 10%, goat's-eye berry (*Galega*) – 10%, hawthorn (*Crataegus azarolus*) – 7%, blackberry (*Rubus caesius*) –8%, spring wheat (*Ranunculus ficaria*) –5%, wild apple (*Malus silvestris*) – 4%, mountain arnica (*Arnica montana*) –3%, perennial daisies (*Bellis perennis*) – 3%, rose hips (*Rosa canina*) – 2%, oak anemone

(*Anemone nemorosa*) – 2%. Of the listed honey plants, the most characteristic for the Carpathians are mountain arnica and oak anemone.

Buckwheat honey was supplied for the study from Sumy, Zhytomyr, Khmelnytsky, Vinnytsia regions - 1 sample each and 2 samples from Lviv region. Buckwheat nectar is collected by bees from mid-June to mid-July. Therefore, the pollen spectrum of this honey mainly contains pollen from plants that bloom during this period. According to the requirements for monofloral buckwheat honey, the content of the main pollen in buckwheat honey should not be lower than 30% of the total number of pollen grains. In the course of our tests, the presence of dominant buckwheat pollen (*Fagopyrum esculentum*) was found at the level of 34-46%. We also found pollen grains of acacia (*Robinia pseudoacacia*) in the amount of 6-15%, meadow clover (*Trifolium pratense*) - 4-11%, yellow sweet clover (*Melilotus officinalis*) - 4-13%, thyme (*Thymus*) - 5-8%, common oregano (*Origanuv vulgare*) - 6-12%, St. John's wort (*Hypericum*) - 5-8%, white mustard (*Sinapis alba*) - 6-12%, motherwort (*Leonurus*) - 2-7%, string (2-8%), spotted thistle (*Silybum marianum*) 7-10%, sainfoin (*Onobrychis arenaria*) in the amount of 2-5%.

Table 2

Relative number of dominant pollen grains in the studied floral honey, %

Honey classification	Types of honey	Dominant pollen name	Proportion of dominant pollen grains:	
			According to Honey Requirements*	Research results
Monofloral	Acacia Honey, n=3	*Robinia pseudoacacia*	≥ 20	23–42
	Buckwheat Honey, n=6	*Fagopyrum esculentum*	≥ 30	34–46
	Linden honey, n=1	*Tilia platyphyllos*	≥ 20	30
	Rapeseed honey, n=10	*Brassica napus*	≥ 30	55–74
	Sunflower honey, n=13	*Helianthus annuus*	≥ 30	48–69
Polyfloral	Flower honey, n=121	–	< 30**	2–19
			< 20***	

Where: * – Order approving the requirements for medical, 2019;
** – for all types of honey;
*** – for acacia and linden honeys.

Only one was identified as linden honey. The nectar for this type of honey was collected in Zakarpattia. Linden trees in Ukraine usually bloom from mid-June to late July. The content of the main pollen of the broadleaf linden (*Tilia platyphyllos*) was 30%. In addition, pollen grains of the following plants were found: blueberries (Vaccinium myrtillus) - 15%, lingonberries (*Vaccinium vitis-idaea*) - 12%, yarrow (*Carpathian*) - 9%, St. John's wort (*Hypericum perforatum*) - 8%, oregano (*Origanum vulgar*) - 6%, mountain arnica (*Arnica montana*) - 4%, broad-leaved thyme (*Thymus pulegioides*) - 3%, mosquito broom (*Gymnadenia conopsea*) - 3%, Carpathian bells (*Campanula carpatica*) - 2%, medicinal goat's-ear (*Galega officinalis*) - 2% and other pollen grains in the amount of less than 1%, which belonged to the families Boraginaceae, Asteraceae. The endemic species of plants of the Carpathians should be distinguished - Carpathian bells, Carpathian yarrow, mountain arnica and mosquito bugle.

Rapeseed honey was also tested - 1 sample each from Chernihiv, Poltava, Kyiv and 7 samples from Vinnytsia regions. The relative amount of dominant pollen of winter rape

(Brassica napus) ranged from 55 to 74%, which confirms the monoflorality of this type of natural honey. In the analyzed samples of rapeseed honey, auxiliary pollen grains of fruit trees were most often found, namely: apple (*Malus*), their share in the pollen spectrum was 9-18%, cherry (*Prunus cerasus*) - 11-15%, pear (*Pyrus communis*) - 4-9%, plum (*Prunus domestica*) - 3-6%, as well as such trees as yellow acacia (*Caragana*) - 7-10%, bird cherry (*Prunus padus*) - 2-8%. In addition, pollen grains of grasses were found. These are mainly the following plants: white sweet clover (*Melilotus albus*) - 8-14%, medicinal dandelion (*Taraxacum officinale*) - 6-10%, common lungwort (*Pulmonaria*) - 4-7%, hogweed (*Corydalis*) - 5-6%, spring wheat (*Ficaria verna*) - 3-6%, sainfoin (*Onobrychis viciifolia*) - 2-5%, medicinal goat's-ear (*Galega officinalis*) - 2-4%.

10 samples of sunflower honey from Khmelnytsky, Kherson, Odesa, Cherkasy, Volyn, Kyiv, Poltava, Rivne - 1 sample each, Ternopil - 2 samples, and Kirovohrad - 3 samples were studied. After analyzing the pollen composition of sunflower honey from different regions of Ukraine, it was found that the content of dominant sunflower pollen grains is in the range of 45-72%, so all samples can be classified as monofloral honeys.

Sunflower blooms in July-August and is a good honey plant, providing bees with nectar and pollen. The relative amount of the main pollen grains (*Helianthus annuus*) in sunflower honey samples ranged from 48-69%. The content of pollen grains of other plants, which were most often recorded in the total species composition of sunflower honey, reached the following values: 9-14% for common bruise (*Echium vulgare*), 4-12% for field thistle (*Cirsium arvense*), 7-11% for blue cornflower (*Centaurea cyanus*), 8-11% for forest angelica (*Angelica sylvestris*), 2-11% for Siberian hogweed (*Heracleum sibiricum*), 5-10% for motherwort (*Leonurus*), 6-10% for common oregano (*Origanum vulgare*), 4-9% for milk thistle (*Silybum marianum*), 4-7% for yarrow (*Achillea millefolium*), 3-6% - garden viper (*Dracocephalum moldavica*), 3-5% - peppermint (*Mentha piperita*), 2-5% - catnip (*Nepeta cataria*), 2-5% - knotweed (*Scrophularia nodosa*).

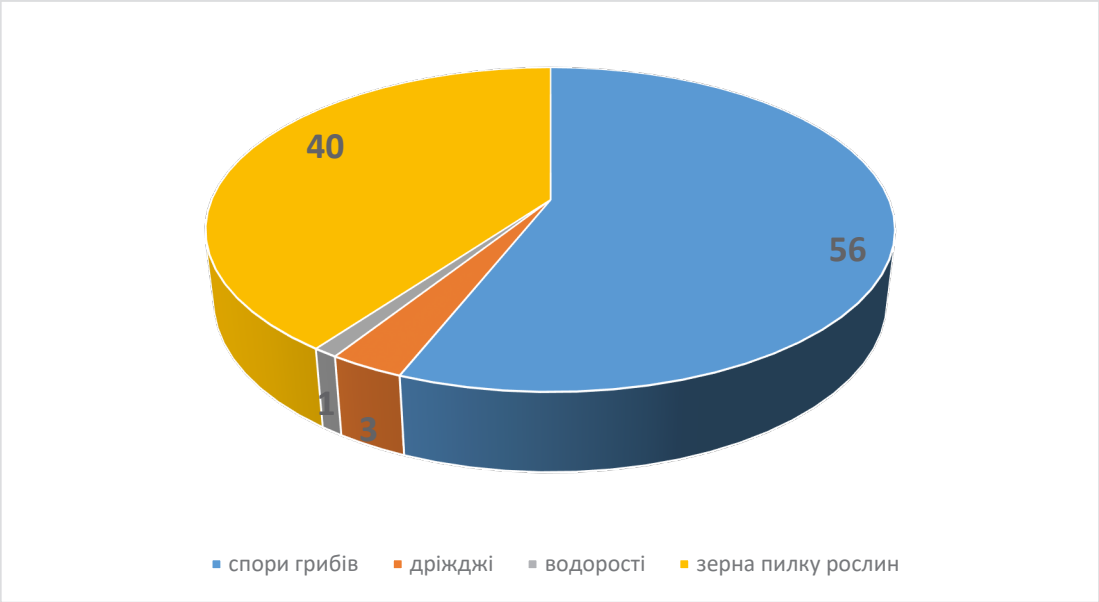
The flower honey samples come from the following regions: Volyn - 3 samples, Rivne - 4, Vinnytsia - 8, Ternopil - 3, Khmelnytskyi - 7, Lviv - 6, Chernivtsi - 2, Zhytomyr - 5, Chernihiv - 2, Kyiv - 6, Sumy - 7, Cherkasy - 6, Dnipro - 9 samples, Zaporizhzhia - 3, Kirovohrad - 10, Kherson - 2, Mykolaiv - 11, Odesa - 5, Poltava - 11, Kharkiv - 11.

It should be noted that there is no characteristic composition of pollen grains of flower honey, since such honey is collected during the entire period of honey harvesting from a variety of grasses: meadow, steppe, and field. Pollen grains of the following honey plants were most often present in the studied samples: biennial evening primrose (*Oenothera biennis*) in the amount of 9-19%, horned larkspur (*Lotus corniculatus*) - 8-17%, yellow sweet clover (*Melilotus*) - 6-15%, field itch (*Knautia arvensis*) - 9-16%, comfrey (*Symphytum officinale*) - 8-13%, lemon balm (*Melissa officinalis*) - 7-13%, meadow cornflower (*Centaurea jacea*) - 8-12%, white ash (*Lamium album*) - 5-12%, sage (*Salvia officinalis*) - 5-8%, *Cynoglossum officinale* - 3-7%, *Onopordum acanthium* - 4-6%, *Marrubium vulgare* - 3-6%, *Echinops ritro* - 2-7%, knotted ranunculus (*Scrophularia nodosa*) - 2-7%, straight cinquefoil (*Stachys recta*) - 2-5% and other pollen grains of plants from the families *Fabaceae, Asteraceae, Caryophyllaceae,* and *Brassicaceae*.

Two samples of honeydew honey were also found. One came from the Kharkiv region, the other from Zakarpattia. A characteristic feature of honeydew honey is the presence of spores of fungi, yeasts and algae, which are classified as honeydew elements. Yeasts prefer sugar-rich substrates: tree sap, plant leaves, fruits, flower nectar. The most common yeasts are of the genus Pichia, Candida, Ambroziozyma.

The spectrum of honeydew elements and pollen grains in honeydew honey from the Kharkiv region is shown in Fig. 2. This honey was characterized by a high content of spores of fungi *Cytospora, Laetiporus, Alternaria, Uncinula*, etc. Yeast and green algae were also present.

The total number of fallen elements in the percentage ratio reached 60%, including fungal spores - 56%, yeast - 3%, and algae - 1%. In addition to the elements typical for honeydew honey, pollen grains of common vetch (*Vicia sativa*) - 5%, comfrey (*Symphytum officinale*) - 3%, tansy (*Tanacetum vulgare*) - 3%, yarrow (*Achillea millefolium*) - 2% were also recorded, *Bidens tripartita* - 2%, *Pisum sativum* - 2%, *Taraxacum officinale* - 1%, *Consolida regalis* - 1%, *Aesculus hippocastanum* - 1%, *Acer platanoides* - 1%, *Ranunculus acris* - 1%, and acrid maple - 1%. Some pollen inclusions that amounted to less than 1% belonged to the most common families in Ukraine - *Asteraceae, Fabaceae* and *Lamiaceae*.



Fungal spores (56) Yeasts (3) Algae (1) Plant pollen grains (40)

Fig. 2. Spectrum of honeydew elements and pollen grains in honeydew honey from Kharkiv region, %

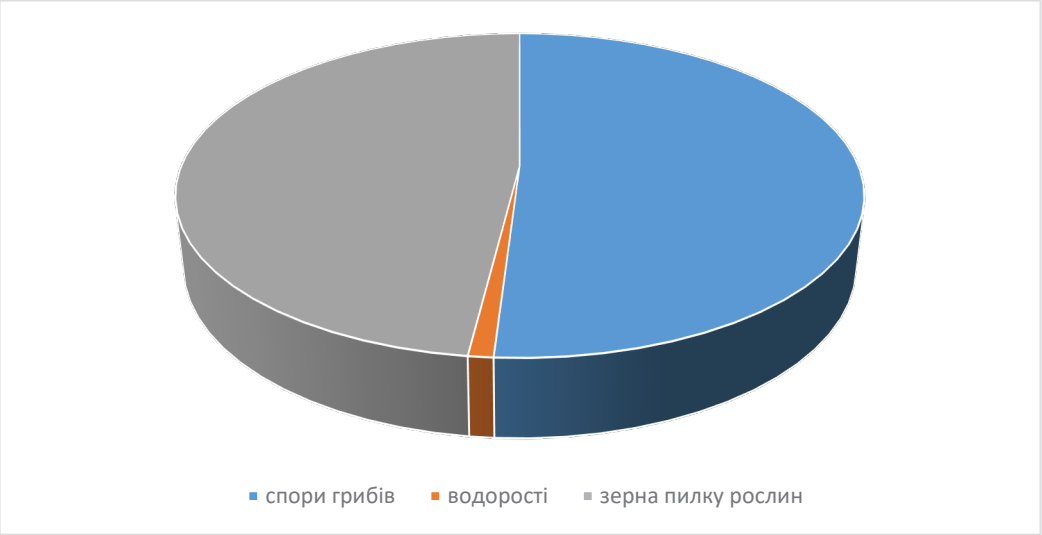
Microscopic analysis of honeydew honey from Zakarpattia region revealed spores of fungi *Uredinales, Peronosporales, Psaterella, Gloesporium*, etc. The relative total amount of fall elements was 52%, of which fungal spores were 51% and algae were 1% (Fig. 3).

Pollen composition is represented by grains of the following plants: reddish clover (*Trifolium rubens*) - 9%, common bruise (*Echium vulgare*) - 6%, medicinal lungwort (*Pulmonaria officinalis*) - 4%, medicinal sage (*Salvia officinalis*) - 3%, chamomile (*Matricaria chamomilla*) - 3%, tansy (*Tanacetum vulgare*) - 3%, wormwood (*Artemisia vulgaris*) - 2%, yarrow (*Achillea distans*) - 2%, field forget-me-not (*Myosotis arvensis*) - 1%, white lupine (*Lupinus albus*) - 1%, and some pollen inclusions of *Asteraceae, Lamiaceae* and *Rosaceae* were also present.

Discussion. All analyzed honey samples differed in organoleptic characteristics and species composition of pollen grains. It is known that the color of honey is affected by the season, bee breed, honeycomb quality, method of pumping, heating, conditions and duration of storage, and primarily depends on the botanical origin, since the composition of pigments in nectar is characteristic of a certain type of honey plants. Derivatives of carotene, xanthophyll and chlorophyll give light varieties of honey a yellow or greenish color. But dark varieties of honey are colored by anthocyanins and tannins. Shades of honey color are also determined by the geographical origin of honey plants (Bertoncelj, 2007).

During storage, the consistency of bee honey changes due to the formation of sugar crystals. The ability of flower honey to crystallize and the speed of this process primarily depends on the ratio of glucose to fructose. The ratio of glucose to fructose is influenced by

the botanical origin of bee honey. Therefore, the ratio of glucose to fructose varies from honey to honey. The more glucose relative to fructose, the faster honey crystallizes. Conversely, the more fructose, the slower the crystallization process (Scripca, 2018). That is why white acacia honey remains liquid for a long time (Escuredo, 2014; Da Silva, 2016). The process of crystallization of honeydew honey depends on the content of dextrins, which delay the formation of crystals. But the melicitosis present in honeydew honey accelerates crystallization. In addition, honeydew honey contains a significant proportion of fructose, which can reach 65%, and a small proportion of glucose, about 15%. Obviously, the consistency and degree of crystallization inherent in each particular type of honey is determined by the qualitative and quantitative parameters of the pollen composition.



Fungal spores (48) Algae (1) Plant pollen grains (51)

Fig. 3. Spectrum of honeydew elements and pollen grains in honeydew honey from Zakarpattia region, %

The color of the honey samples ranged from colorless to dark brown, the aroma was unevenly expressed, and the taste had different astringency and sweetness. Each type of honey had a unique consistency and type of crystallization. These characteristics of bee honey are related to the botanical species of the nectar source and the region of its collection.

The relationship between organoleptic characteristics and botanical origin of honey has been observed by a number of researchers (Adamchuk, 2014; Machado De-Melo, 2018; Hamid, 2021).

Of interest to scientists is the question of the relationship between not only organoleptic, but also physicochemical indicators of bee honey quality and its botanical origin. Thus, the dependence of the main quality indicators of monofloral honey on the content of accompanying pollen grains, even with the same content of the dominant pollen, has been established (Chakir, 2016; Oroian, 2017; Majewska, 2019; Lazareva, 2023, 2024).

There is an assumption that the proportion of the dominant plant in the pollen spectrum also affects the sugar composition of the studied honey and its organoleptic properties (Adamchuk, 2014; Bentabol Manzanares, 2017).

Nevertheless, pollen analysis is a more accurate and reliable method for determining the origin and type of honey.

Research on the pollen composition of bee honey is relevant in view of compliance with the Requirements for honey, which provide for ensuring proper consumer information and preventing consumers from being misled in business practice.

Establishing the species composition of pollen grains in floral honeys makes it possible to determine the dominant pollen origin of a certain plant species and confirm its monoflority, either, in the absence of dominant pollen, polyflority.

Note that some plants produce a lot of pollen, for example, chestnut, and others, on the contrary, a little - *Robinia vulgaris* (white acacia), therefore this fact must be taken into account when establishing norms for the dominant honey plant (Adamchuk, 2022).

It has been established that the pollen composition of flower honey of a certain botanical origin may also include pollen from plants that have bloomed earlier and were the main honey plants for collecting honey of another species. Since during honey extraction, beekeepers often leave a small part of it in the honeycombs to feed the bees. Or, for a small bribe, they may skip one of the honey extractions altogether. And so, in this way, the remains of honey, together with characteristic pollen, can get into the honey of the next extraction. In addition, there are different ways in which pollen enters honey. Thus, there is a distinction between primary pollen of bee honey, which is naturally present in the nectar of flowers. Later, in the process of honey ripening, secondary pollen enters the unsealed cells. This can be pollen from the bee body, as well as from the mouthparts of bees that feed on it and are involved in the process of exchanging and processing pollen and nectar. At the same time, the pollen composition of honey does not change dramatically, because the pollen of those honey plants from which the bees collected nectar mainly enters the honey. In the process of pumping honey, tertiary pollen may appear, which is sealed in the honeycombs in the form of pollen. However, under the conditions of the centrifugal method of pumping bee honey, which is usually used in practice, pollen remains in the honeycombs.

Our research has established that the most common pollen grains in the studied honey were from the most common honey plants in Ukraine, which belonged to the families *Asteraceae, Brassicaceae, Fabaceae, Lamiaceae, Rosaceae, Caryophyllaceae,* and *Boraginaceae*.

Pollen analysis reveals the origin of the raw material from which honey is produced - nectar or honeydew. Authentication of honey by pollen spectrum (profile) allows you to detect honeydew elements, which may include fungal spores (*Alternaria, Helminthosporium, Uncinula* and others), yeast (*Metschnikowia reukafii* and others), green algae. Due to the fact that other particles are filtered out with pollen, melisopalynological analysis makes it possible to assess the contamination of honey with mechanical impurities (Adamchuk, 2021).

According to the pollen spectrum, honeydew honeys are characterized by the highest percentage of fungal spores, often the composition of honey also includes fungi themselves, for example, *Metschnikowia reukafii* yeast and others, as well as green algae (Seijo, 2019).

The botanical and regional origin of bee honey in Ukraine is studied by a number of scientists. It has been confirmed that bee honey is a unique product and is able to change its composition within one species, regardless of monofloral and geographical origin (Lazareva, 2015; Lisogurska, 2019).

Currently, only humans are able to identify the botanical affiliation of countless variations of individual pollen grains in flower honey. It is worth noting that such an analysis of the pollen composition of flower honey requires a specialist of high professionalism. One should not forget about another drawback of the microscopic method of research of the pollen composition of bee honey - the inability to accurately estimate the proportion of unknown pollen that is present in the field of view during the counting of pollen grains.

Therefore, attempts are being made to use computer processing of pollen images, but so far without success, since modifications of its shape and size are extremely diverse and at the same time can have significant similarities within related species, and sometimes even plant families.

It is necessary to mention the methods of establishing the botanical origin of honey, based on the analysis of specific components, or on multicomponent analysis. They are mostly

focused on the study of the structure of flavonoids, aromatic compounds and special marker compounds, etc. Analysis of the profiles of such components as oligosaccharides, amino acids, trace elements can probably be used to determine the geographical origin. A combination of methods can be one of the approaches to confirm authenticity (Anklam, 1998; Bogdanov, 2004; Azevedo, 2017).

Today, the demand for monofloral and paddy honey is growing in the world, the latter in some countries being considered even more valuable and beneficial for the human body than floral honey (Cal Orey, 2011). Considering the species diversity of the flora of Ukraine, which provides many types of bee honey, it can be argued that our country has the potential to maintain the status of a powerful exporter of natural honey.

There is a need to study and develop in Ukraine more modern methods of researching the botanical and geographical origin of honey, such as nuclear magnetic resonance spectroscopy of the hydrocarbon profile, with the creation of a database of unique spectrograms for each honey sample, which is an identifier of the authenticity of honey. For example, isotope analysis mass spectrometry (IRMS), as a confirmatory method.

Conclusions.

The conducted studies of the botanical origin of bee honey confirmed the fact that even within one monofloral species, each individual sample had a unique composition of pollen grains, which also affected its organoleptic characteristics.

Pollen analysis of natural honey made it possible to establish the origin of the raw material processed by bees - nectar or honeydew. Confirm the monofloral or polyfloral nature of flower honey.

These tests provide valuable information not only on the botanical origin of honey. Thus, despite the fact that a significant part of honey plants are distributed throughout the territory of Ukraine, each of the regions has endemic plants. Given this, it is possible to establish the geographical origin of bee honey by its pollen composition. Which in turn helps to assess the plant composition and changes in the ecosystem of the region where bee honey comes from.

The prospect of Ukraine's leadership among bee honey exporters to the European Union countries and taking into account the complexity of conducting a study of the species composition of pollen grains by microscopic method, there is a need to search for and develop more effective and accurate methods to confirm the botanical and regional origin of bee honey.

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ДОСЛІДЖЕННЯ БОТАНІЧНОГО ПОХОДЖЕННЯ БДЖОЛИНИХ МЕДІВ УКРАЇНИ

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Резюме. *Мета досліджень полягала в аналізі бджолиних медів України за органолептичними показниками та видовим складом пилкових зерен, встановити їх походження, вид та ботанічну однорідність. Дослідження органолептичних показників та пилковий склад меду бджолиного проводили за допомогою методів, зазначених у ДСТУ 4497:2005 «Мед натуральний. Технічні умови». Ботанічну однорідність, тобто монофлорність або поліфлорність, визначали керуючись Наказом про затвердження Вимог до меду (Наказ МАППУ № 330 Про затвердження Вимог до меду, 2019). Нами проаналізовано 156 зразків меду бджолиного, отриманого з різних регіонів України. Встановлена відповідність вимогам щодо якості меду натурального за органолептичними показниками. З'ясовано різноманітність ботанічного походження. Аргументовано монофлорність 33 проб меду та поліфлорність 121 проби шляхом дослідження видового складу пилкових зерен. Окрім того, за результатами випробувань 2 проби віднесено до падевого меду. Нашими випробуваннями підтверджений неповторний пилковий склад кожного окремого меду бджолиного, від якого залежать органолептичні властивості. За допомогою пилкового аналізу меду бджолиного можна встановити не лише вид сировини, ботанічний склад меду, а й географічне походження. Зважаючи на складність виконання мікроскопічного методу вивчення видового складу пилкових зерен бджолиного меду, є необхідність пошуку нових методів досліджень.*

Ключові слова: бджолиний мед, органолептичні показники, пилковий аналіз, домінуючі пилкові зерна, походження меду

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