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SPECIFIC FEATURES OF ACCUMULATION OF ORGANOCHLORINE PESTICIDE RESIDUES IN MELLIFEROUS PLANTS, BEE POLLEN, AND HONEY

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Abstract. Honey is a natural product made by honeybees. It contains minerals, vitamins, simple sugars, organic acids, antioxidants, and enzymes, that is why it is considered to have good nutritional and therapeutic properties. However, honey loses a lot of its benefits if it is contaminated with foreign chemicals such as pesticides. The purpose of this research was studying how pesticide residues accumulated in different types of melliferous flowers, in bee pollen, and in honey obtained in the Odessa Region during the years 2015–2017. The gas-liquid chromatography method was used to investigate 121 samples of flowers of melliferous plants and trees, 78 bee pollen samples, and 104 honey samples. We have found that all the samples investigated are positive for such organochlorine pesticides as α, β, γ isomers of hexachlorocyclohexane and dichlorodiphenyltrichloroethane (DDT) and its derivatives in different concentrations. Our study has shown that the sunflower samples were high in organochlorine pesticides. There, the average concentration of α, β, and γ isomers of hexachlorocyclohexane was 7.51±0.04 μg/kg, and that of DDT 6.98±0.02 μg/kg. Flowers of buckwheat and other field herbs (wild herbs as well as crop plants) had lower concentrations of these pesticides. Besides, the results obtained have shown that flowers of fruit trees (cherry, apple, pear, peach, plum) were lower in these pesticides than those of forest trees (black locust, lime-tree). The examination of the bee pollen and honey samples has shown the same picture. The highest contents of α, β, γ isomers of hexachlorocyclohexane and dichlorodiphenyltrichloroethane were in the sunflower samples (their average consentrations being 3.52±0.05 and 3.77±0.03 μg/kg in bee pollen, 2.74±0.01 and 2.53±0.03μg/kg in honey, respectively). However, the concentrations of pesticide residues detected in all samples were below the maximum permissibile level according to national and EU standards. Still, to ensure the quality and safety of honey, we suggest regularly monitoring the levels of pesticide residues in melliferous plants and apiculture products nationwide.

Keywords: α, β, γ isomers of hexachlorocyclohexane, dichlorodiphenyltrichloroethane and its derivatives, gas-liquid chromatography method, melliferous plants, bee pollen, honey.

Introduction. Formulation of the problem

Honey-making is one of the most important farming branches in Ukraine. At the beginning of the year 2000, honey became one of the first farming products allowed to be exported from Ukraine to the EU countries. According to official statistics, Ukraine is the largest producer of honey in Europe and the third largest in the world [1]. It is well-known that due to its significant content of minerals, vitamins, simple sugars, organic acids, antioxidants, and enzymes, honey has good nutritional and therapeutic properties [2-5]. However, they are reduced significantly if honey contains foreign harmful substances. These harmful substances include pesticides. They can get into honey in the two main ways: with contaminated nectar and pollen that honeybees take from melliferous plants, and with certain chemical agents beekeepers use in the technological process [6-9].

According to the EU regulations (Council Directive 2001/110/EC and Regulation (EC) No. 470/2009), honey as a natural product must be free of foreign chemicals, including pesticides [10]. Their presence in honey may be a serious health hazard, especially for children and the elderly, because pesticides are very toxic, and some of them are potential carcinogens. Penetration of pesticides (especially organochlorides) into the human body may result in chromosome mutations and cellular degradation. Pesticides are also known to cause changes in the endocrine, reproductive, immune, and nervous systems [7,11]. In the EU countries and in Ukraine, state authorities monitor the levels of residues of chemical compounds (including those of pesticides) in honey to ensure its safety. This allows controlling the dynamics of pesticide residues accumulation in honey [12,13]. Monitoring studies of honey in Ukraine make it possible to obtain the summarised data on the pesticide content of honey from different regions, because in most cases, objects of analysis are compsite (gross) samples. Thus, consumers have generalised information about all types of honey in a particular region. However, one often needs more detailed toxicological characteristics of honey of different botanic origin: it can be very important to trace certain types of melliferous plants as the source of pesticide-contaminated honey. It is of particular scoentific interest to study different levels of pesticide contamination of honey derived from melliferous plants cultivated as agricultural crops (which undergo pesticide treatment in the field) and from wild plants – these pesticide contamination levels can be quite unpredictable [14,15]. So, studying pesticide residues in honey helps ensure its quality and safety for consumers' health.

Analysis of recent research and publications

A review of literature has shown that honey can be contaminated by different types of pesticides from the environment and during the honey-making technological process [6,7]. But beekeepers are rather worried by the fact that pesticides (insecticides, fungicides, herbicides, and bactericides) are used in agriculture to increase the productivity of plants and protect them from insects [7]. Meanwhile, many agricultural plants are melliferous because their nectar can be collected by bees. The use of chemicals by beekeepers in the honey-making technology can be controlled and avoided, but nobody can control honeybees collecting nectar from agricultural crops.

Organochlorine pesticides (OCP) used in farming are characterised by high chemical stability, low solubility in water, high solubility in organic solvents, and resistance to chemical and biological degradation [8,11]. Researchers' major concern is contamination of the environment with pesticides (especially organochlorides) because they are toxic and pose a threat to people's health, soil, water, animals, and plants [7,11]. In recent years, several studies have reported detecting different levels of agricultural pesticide residues in apiculture products, including honey [8,11]. The presence of pesticides in honey has been investigated in a number of countries, among them China, Serbia, Egypt, Thailand, Iran, Greece, Colombia, Malaysia, Brazil, Italy, Poland, Spain, Bosnia and Herzegovina, France, Argentina, the United States, Turkey, and India [3,6,9,12-19]. These studies confirm how important and urgent it is to study the levels of pesticides in honey and how they get into it.

Council Directive 2001/110/EC determines what basic requirements honey should meet to be able to move freely in the EU market. These regulations provide norms for the amounts of organochlorine pesticides honey can contain: for dichlorodiphenyltrichloroethane and its metabolites, hexachlorocyclohexane (α, β, γ isomers). Their maximum levels must be no more than 5.0 μg/kg [10].

Honey is an important source of income for Ukrainian farmers, especially in the south of Ukraine. This product is imported into EU countries, but information about organochlorine pesticide residues in honey manufactured in this area is still very limited and inadequate [1,2]. Therefore, it is very important to ivestigate honey from the south of Ukraine and, in particular, from the Odessa Region, as it is recognised as one of the potential beekeeping zones in the country.

The **purpose** of the present study is to learn the specific features of accumulation of OCP residues in different melliferous plants, bee pollen, and honey. The samples studied were obtained in 2015–2017 from various apiaries located in the Odessa Region. To study the samles, the gas-liquid chromatography method was used.

To achieve this purpose, the following **objectives** were set:

1. To investigate the levels of the residue amounts of hexachlorocyclohexane (α, β, γ isomers) and dichlorodiphenyltrichloroethane and its derivatives in six groups of melliferous plants, in bee pollen, and in honey.
2. To study the relationship between the levels of residual amounts of organochlorine pesticides in honey and its botanic origin (the type of a melliferous plant).

Research materials and methods

Taking samples. The research was carried out in the microbiology laboratory of the Public Health Department of Sumy State University, and in the Odessa Regional State Laboratory of the State Service of Ukraine for Food Safety and Consumer Protection. A total of 121 samples of flowes from melliferous plants and trees, 78 samples of bee pollen, and 104 samples of honey were investigated. The samples were collected from 9 apiaries located in the Odessa Region (the south of Ukraine) between 2015 and 2017. All the apiaries are located near farmland territories where various pesticides are applied continuously to control the speading of insects or weeds.

Flowers from six groups of plants with melliferous properties were studied: oilseed crops (sunflower) – 22 samples; cereal crops (buckwheat) – 19 samples; fruit trees (cherry, apple, pear, sweet cherry, peach, cherry-plum) – 21 samples; non-fruit trees (black locust) – 23 samples; forage herbs (alfalfa, clover, rapeseed, melilot) – 19 samples; wild herbs (dandelion)– 17 samples; 121 samples in total.

78 samples of bee pollen and 104 samples of honey from the corresponding melliferous plants were also investigated.

Preparation of the samples for investigation. The honey and bee pollen samples were prepared according to the methods given in State Standards of Ukraine ISO 12393-1:2003 and ISO 12393-2:2003. A sample portion of 30.0±0.01 g was mixed in a porcelain mortar with anhydrous sodium sulphate until a mushy mixture was obtained. Pesticides were extracted in 100 cm^3 of acetone on a shaker for 30 min. The extract was decanted through a glass funnel with a layer of anhydrous sodium sulphate into a 250 cm^3 flask. The residue was shaken with an additional 50 cm^3 of acetone for 20 min, and the extract was decanted again through a layer of anhydrous sodium sulphate. The extracts joined together were evaporated on a rotary evaporator at 50°C under low pressure. Before evaporation, 0.5 cm^3 of dodecane was added. The solid residue was dissolved in 5 cm^3 of hexane. Purification was carried out on a Varian (Netherlands) solid phase extraction apparatus with special Varian cartridges used for this method.

Method of determining organochlorine pesticides in the samples. Organochlorine pesticides were determined by gas-liquid chromatography. Prior to this, they had been appropriately extracted from the samples by means of solvents, and the extract had been purified by solid-phase extraction according to State Standarts of Ukraine ISO 12393-3:2003 and ISO 12393-4:2003. Identification was carried out by the retention time, and the quantitative measurement by the peak area using the external standardisation technique. The equipment used for the research is a gas chromatograph Agilent 7890 A GS System (USA), an electron capture detector (ECD/μECD), and a thermionic detector (TID/NPD). Purification was carried out on a Varian (Netherlands) solid phase extraction apparatus with special Varian cartridges used for this method. The research was conducted according to generally accepted methods. The limit of quantification of the methods was 1.0 μg/kg.

Results of the research and their discussion

It is known that the chemical composition and quality of honey depend on many factors, such as the type of the melliferous plants the nectar was collected from, the beekeeping practices, and the conditions of honey storage [2,3,7]. The problem of determining the presence of pesticides (primarily the organochlorine group) in honey is very important for manufacturing safe honey of high quality [20-24]. So, this research is to study the level of OCP residues in different melliferous plants, bee pollen, and honey obtained from various apiaries in the Odessa Region.

The concentration of pesticide residues in plants is known to depend on their biological characteristics, in particular, on their blossoming time. Most plants bloom during the second half of spring and the first half of summer. The flowering period of spring melliferous plants is shorter, that of summer ones is longer, and autumn melliferous plants are not so important in honey-making, because bad weather prevents bees from visiting them. Of all spring melliferous plants, we selected flowers of fruit trees and forest trees to take the samples from, and lime-tree, buckwheat, and sunflower became the source of the samples from summer melliferous plants.

Table 1 presents the data on the residual quantities of OCP contained in melliferous plants.

Table 1 – **Content of organochlorine pesticide residues in melliferous plants and trees, µg/kg (M±m)**

Types of melliferous plants	No. of samples analysed	Level of HCH (α, β, γ isomers)			Level of DDT (and its derivatives)		
		min	max	average	min	max	average
Sunflower	22	7.10±0.01	7.92±0.03	7.51±0.04	6.77±0.03	7.19±0.03	6.98±0.02
Buckwheat	19	3.64±0.03	4.28±0.02	3.96±0.06	3.43±0.02	3.68±0.08	3.56±0.04
Fruit trees*	21	1.77±0.01	2.36±0.09	2.06±0.02	1.65±0.06	1.96±0.01	1.81±0.05
Non-fruit trees**	23	2.55±0.05	2.94±0.03	2.75±0.07	1.98±0.01	2.59±0.03	2.29±0.03
Forage crops***	19	3.55±0.03	3.78±0.01	3.67±0.01	3.27±0.02	3.59±0.02	3.43±0.02
Wild herbs	17	2.12±0.01	2.44±0.02	2.28±0.05	1.55±0.08	1.97±0.03	1.76±0.01

Note: *Fruit trees: cherry, apple, pear, peach, cherry-plum; **Non-fruit trees (forest trees): false acacia (black locust), lime-tree;

***Forage crops: alfalfa, clover, rapeseed, melilot.

As it can be seen from Table 1, in the samples of honey from sunflower, buckwheat, and forage crops, OCP residual amounts were found more often and in higher concentrations. The flowers of sunflower were found to contain significantly higher concentrations of OCP.

Our research allowed establishing that in sunflower flowers, the maximum concentration of HCH (α, β, γ isomers) was 7.92±0.03 μg/kg, and the content of DDT (and its derivatives) ranged 6.77±0.03 to 7.19±0.03 μg/kg.

The pesticide content in flowers of fruit and non-fruit trees was insignificant and lower than that in sunflowers by 3.6 and 2.7 times on average. Such results can be explained by the fact that far more pesticides are used to cultivate sunflowers than in orchards. The presence of OCP in flowers of wild melliferous plants is due to their natural circulation with rainwater and soil dust, and dispersal by wind.

V. Cebotari et al. from the Republic of Moldova, in their research (2018), determined the concentrations of systemic pesticides in flowers of forest trees (false acacia and large-leaved lime), which are the main sources of nectar and pollen for Moldovan honeybees. These concentrations were 1.3 to 33.3 times lower than the maximum permissible limits, according to national and EU standards [10]. Several authors from others countries obtained the same results and suggested that flowers of farm crops and fruit trees that were treated with pesticides could be sources of OCP in pollen and honey more often than flowers of wild herbs and trees [6,14,15,23,24].

The results of studying bee pollen are shown in Table 2. All bee pollen samples investigated proved to be positive for both groups of organochlorine pesticides. The highest concentrations of HCH (α, β, γ isomers) and DDT with its derivatives were detected in sunflower pollen.

Table 2 – **Content of organochlorine pesticide residues in bee pollen, μg/kg (M±m)**

Bee pollen from melliferous plants	No. of samples analysed	Level of HCH (α, β, γ isomers)			Level of DDT (and its derivatives)		
		min	max	average	max	min	average
Sunflower	18	3.27±0.01	3.78±0.07	3.52±0.05	3.26±0.04	2.28±0.01	3.77±0.03
Buckwheat	9	2.39±0.01	2.76±0.06	2.57±0.07	1.98±0.02	2.79±0.02	2.39±0.01
Fruit trees*	16	1.15±0.07	1.78±0.01	1.47±0.03	1.37±0.01	1.76±0.07	1.57±0.06
Non-fruit trees**	12	1.45±0.05	1.94±0.06	1.55±0.04	1.57±0.05	1..95±0.04	1.76±0.01
Forage crops ***	14	2.94±0.03	3.55±0.03	3.25±0.01	2.54±0.07	3.19±0.02	2.87±0.01
Wild herbs	9	1.69±0.07	2.19±0.09	1.94±0.06	1.39±0.02	1.77±0.01	1.58±0.04

Note: *Fruit trees: cherry, apple, pear, peach, cherry-plum; **Non-fruit trees (forest trees): false acacia (black locust), lime-tree;

***Forage crops: alfalfa, clover, rapeseed, melilot.

The data from Table 2 show that concentrations of HCH (α, β, γ isomers) in bee pollen were higher that concentrations of DDT and its derivatives. These pesticides were found in all samples, but their content was the highest in bee pollen taken from sunflower compared to that from other melliferous plants. The smallest residual amount of pesticides was detected in bee pollen from flowers of fruit and non-fruit trees and of wild herbs.

On average, the maximum residual amounts of HCH (α, β, γ isomers) and of DDT (and its derivatives) in flowers of melliferous plants and trees were, respectively, 1.5–2.1 times and 1.85–1.02 times higher than in bee pollen. These data are consistent with a lot of other data regarding the sourses of pesticides in honey that are closely related to a melliferous plant [6,8]. J. Ruiz-Toledo et al. (2018) reported that pollen samples were the highest in pesticides (14 out of 16) in the highest concentrations [9].

There are a lot of scientific publications reporting the presence of pesticides in honey and other bee products. Ż. Bargańska et al. (2014) reported that 19 pesticides were detected in honey samples from the north of Poland. The minimum detectable concentrations of pesticides (including organochlorides) ranged 0.91–25 ng/g [17]. C. Blascob et al. (2016) found residues of nine organochlorine pesticides (α, β, and γ-hexachlorocyclohexane (HCH), hexachlorobenzene (HCB), aldrin, *p*, *p*′-DDE, *p*, *p*′-DDD, *o*, *p*′-DDT, and *p*, *p*′-DDT) in honey samples selected on markets of Portugal and Spain. The levels were between 10 and 100 μg/kg for β-HCH and for p, p′-DDT, and between 20 and 200 μg/kg for α-HCH and γ-HCH. Many other studies showed similar results [19]. So, residual quantities of pesticides in honey vary with each country. This can be explained by different intensity with which means of plant protection are used in farming. Below, Table 3 presents the results of our research of the level of OCP residues contained in honey made in the Odessa Region.

As we can see from the data given in Table 3, OCP residues were found in the samples of honey from flowers of sunflower, forage crops, and buckwheat. However, it should be noted that the quantities of OCP found in these honey samples were almost twice as low as the specified levels.

The smallest residual amounts of the pesticides in question were found in honey from wild flowers, and from flowers of fruit and non-fruit trees. It is very important that the OCP content in honey from fruit trees, non-fruit trees, and wild herbs was <1.0 μg/kg. Such honey is characterised as being free of these pesticides.

Permissible residues of organochlorine pesticides in foodstuffs, including honey, are regulated by a number of national and international laws and statements. According to these documents, the maximum allowable level of organochlorine pesticides is 5.0 μg/kg.

B. Kartalovic et al. investigated organochlorine residues in honey samples from the Pannonian region in the Republic of Serbia. They found organochlorine pesticides in all honey samples. But all pesticide concentrations detected were below the maximum allowed value [18]. F. Eissa et al. studied 18 honey samples from Egypt, and found organochlorine and organophosphorous pesticide residues in 55.6% of the samples [22]. I. Mujic et al. analysed 46 honey samples for pesticides, heavy metals, radioactive elements, and antibiotic residues, and found no pesticides [24].

In Table 4 below, we have summarised the data on the content of residues of HCH (α, β, γ isomers) and DDT with its metabolites in melliferous plants, bee pollen, and honey. This gives a clearer idea of the dynamics of accumulation of these pesticides on their way from a certain melliferous plant to honey obtained from it.

The data presented in Table 4 show the following regularities: all samples from flowers of melliferous plants, bee pollen, and honey contained more HCH (α, β, γ-isomers) than DDT and its derivatives; there was a predictable decrease in the content of both pesticide groups on the way from a honey plant to honey; the highest level of the pesticides considered was in flowers, bee pollen and honey from plants that, while cultivated, had been treated with chemical agents; HCH (α, β, γ isomers) and DDT and its derivatives were insignificant in honey and bee pollen from fruit, non-fruit trees, and wild herbs, and the presence of these pesticides in honey may be due to their natural transfer with dust, wind, and rainwater.

As proved by a number of scientists, the content of pesticide residues in honey is largely influenced by its botanical origin. This fact is explained by the ability of honey plants to accumulate pesticides from the environment. The source of pesticides found in honey is mostly agricultural crops [6,8,13]. It is important that in honey produced in the south of Ukraine (Odessa Region), according to our research data, the residual level of HCH (α, β, γ isomers) and DDT and its derivatives is within the limits permitted by food regulations.

Table 3 – **Content of organochlorine pesticide residues in honey, μg/kg (M±m)**

Honey produced from different melliferous plants	No. of samples analysed	Level of HCH (α, β, γ isomers)			Level of DDT (and its derivatives)		
		min	max	average	min	max	average
Sunflower honey	23	2.49±0.01	2.98±0.03	2.74±0.01	2.17±0.02	2.89±0.05	2.53±0.03
Honey from buckwheat	12	1.88±0.02	2.06±0.01	1.93±0.03	1.78±0.05	1.92±0.01	1.84±0.01
Honey from fruit trees*	19	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Honey from non-fruit trees**	18	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Honey from forage crops***	21	2.02±0.01	2.28±0.01	2.15±0.05	1.55±0.07	1.79±0.01	1.67±0.03
Honey from wild herbs	11	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

Note: *Fruit trees: cherry, apple, pear, peach, cherry-plum; **Non-fruit trees (forest trees): false acacia (black locust), lime-tree;

***Forage crops: alfalfa, clover, rapeseed, melilot.

Table 4 – Average content of HCH (α, β, γ isomers) and DDT (and its metabolites) in melliferous plants, bee pollen, and honey, μg/kg (M±m)

Melliferous plants	Level of HCH (α, β, γ isomers)			Level of DDT (and its derivatives)		
	Melliferous plants	Bee pollen	Honey	Melliferous plants	Bee pollen	Honey
Sunflower	7.51±0.04	3.52±0.04	2.74±0.01	6.98±0.02	3.77±0.03	2.53±0.03
Buckwheat	3.96±0.04	2.57±0.07	1.93±0.03	3.56±0.04	2.39±0.01	1.84±0.01
Fruit trees*	2.06±0.02	1.47±0.03	<1.0	1.81±0.05	1.57±0.06	<1.0
Non-fruit trees**	2.75±0.07	1.55±0.04	<1.0	2.29±0.03	1.76±0.01	<1.0
Forage crops ***	3.67±0.01	3.25±0.01	2.15±0.05	3.43±0.02	2.87±0.01	1.67±0.03
Wild herbs	2.28±0.05	1.94±0.06	<1.0	1.76±0.01	1.58±0.04	<1.0

Note: *Fruit trees: cherry, apple, pear, peach, cherry-plum; **Non-fruit trees (forest trees): false acacia (black locust), lime-tree;

***Forage crops: alfalfa, clover, rapeseed, melilot.

Conclusion

1. This study has proved that honey from different melliferous plants and trees of the Odessa Region does not contain OCP above the maximum permissible level, so it can be considered toxicologically safe.
2. In the investigated samples of honey, HCH (α, β, γ isomers) has been detected in higher concentrations than DDT and its derivatives.
3. The content of HCH (α, β, γ isomers) in the honey samples ranged from <1.0 to 2.74±0.01 μg/kg, the content of DDT and its derivatives from <1.0 to 2.53±0.03 μg/kg.
4. The highest concentration of organochlorine pesticides has been found in sunflower honey, where it averaged 2.74±0.01 μg/kg for HCH (α, β, γ isomers) and 2.53±0.03 μg/kg for DDT and its derivatives.
5. A regular feature has been established that flowers of melliferous plants contained, on average, 2.0–2.8 times as much HCH (α, β, γ isomers) and 1.8–2.7 times as much DDT (and its derivatives) as honey, and, respectively, 1.4–2.1 and 1.2-1.9 times as much of these as bee pollen.

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ОСОБЛИВОСТІ НАКОПИЧЕННЯ ЗАЛИШКІВ ХЛОРОРГАНІЧНИХ ПЕСТИЦИДІВ В МЕДОНОСНИХ РОСЛИНАХ, БДЖОЛИНОМУ ОБНІЖЖІ ТА МЕДІ

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Анотація. Мед – це натуральний продукт, вироблений медоносними бджолами, який за рахунок наявності в ньому мінеральних речовин, вітамінів, простих цукрів, органічних кислот, антиоксидантів і ферментів, вважається продуктом з гарними поживними та лікувальними властивостями. Всі корисні характеристики меду знижуються, якщо він забруднений сторонніми хімічними речовинами, у тому числі й пестицидами. Метою даного дослідження було вивчення накопичення залишків пестицидів у квітках різних типів медоносних рослин, бджолиному пилку та меді, отриманих в Одеській області протягом 2015–2017 років. За допомогою методу рідинної хроматографії було досліджено 121 зразків квітів з медоносних рослин і дерев, 78 зразків бджолиного пилку та 104 зразки меду. Ми виявили, що всі досліджені зразки були позитивними до таких хлорорганічних пестицидів як α, β, γ–ізомери гексахлорциклогексану і дихлордифенілтрихлорметилметану та його похідних в різних концентраціях. Нашими дослідженнями було встановлено, що серед зразків медоносних рослин, високий рівень хлорорганічних пестицидів був у зразках квітів соняшнику з середньою концентрацією α, β, γ–ізомерів гексахлорциклогексану 7.51±0.04 мкг/кг та ДДТ 6.98±0.02 мкг/кг. Цвіт гречки та інших польових трав (включно польове різнотрав'я та культурні рослини) мали меншу концентрацію цих пестицидів. Окрім того, отримані результати показують, що у квітах плодових дерев (вишня, яблуня, груша, вишня, персик, слива) була нижча концентрація досліджуваних пестицидів ніж у квітах лісових дерев (біла акація, липа). Результати обстеження бджолиного пилку та зразків меду показують таку ж ситуацію. Найвища концентрація α, β, γ–ізомери гексахлорциклогексану та дихлордифенілтрихлорметилметану була у зразках соняшникового походження з середньою концентрацією 3.52±0.05 та 3.77±0.03 мкг/кг у бджолиному пилку, 2.74±0.01 та 2.53±0.03 мкг/кг – у меді відповідно. Проте, виявлені концентрації залишків пестицидів у всіх досліджуваних зразках були меншими, ніж граничні допустимі рівні, зазначені у національних та європейських стандартах. Незважаючи на це, ми пропонуємо регулярний моніторинг залишків пестицидів у медоносних рослинах та в продуктах бджільництва на національному рівні для забезпечення якості та безпеки меду та захисту здоров'я споживачів.

Ключові слова: α, β, γ–ізомери гексахлорциклогексану, дихлордифенілтрихлорметилметан та його похідні, метод газорідинної хроматографії, медоносні рослини, мед, бджолиний пилок.

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