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PECULIARITIES OF BEE PROTEIN PRODUCTION AND INTENSITY OF ITS CONTAMINATION WITH ^{137}CS AND ^{90}SR IN THE CONDITIONS OF HONEY-GROWING LANDS OF THE FOREST-STEPPE AND POLISSYA

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One of the priority areas of social development in Ukraine is to provide the population with high-quality and safe food raw materials, among which bee products containing a number of biologically active substances, namely vitamins, carbohydrates, amino acids, minerals, flavonoids, melanins, etc. are in high demand. Most of these substances have highly nutritional therapeutic and prophylactic properties, including immunostimulating, radioprotective, antioxidant, sorption, etc. These properties of bee products provide a wide range of uses in public nutrition and medical practice for therapeutic purposes.

It is known that the quality and safety of bee protein products depend on the ecological condition of honey-growing lands. Their current state in some areas of Ukraine has been subjected to anthropogenic contamination, in particular with ^{137}Cs and ^{90}Sr radionuclides as a result of the Chornobyl accident, which has led to a decrease in their quality, production efficiency, and reduced demand and use.

It has been established that among bee products produced in the areas of honey-bearing lands contaminated with ^{137}Cs (1–5 Ci/km^2) and above, flower pollen and beehive have a several times higher intensity of contamination compared to honey and wax. At the same time, the permissible level of radionuclides in bee pollen and feathers produced on these honey-growing areas was found to be exceeded.

Taking into account the requirements for permissible levels of radionuclides in beekeeping products under the 2006 State Standard, which have significantly increased compared to the 1991 State Standard due to a 3-fold decrease in specific activity of ^{137}Cs and ^{90}Sr in bee nuc, pergola, and drone larvae homogenate, respectively, there is a need to study the intensity of contamination of these products and develop ways to improve their quality.

The need for such studies is due to the social task of reducing the level of radiation pressure on the population.

Key words: *honey lands, beekeeping, propolis, contamination, bee pollen, protein products.*

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ОСОБЛИВОСТІ ВИРОБНИЦТВА БІЛКОВОЇ ПРОДУКЦІЇ БДЖІЛЬНИЦТВА ТА ІНТЕНСИВНІСТЬ ЗАБРУДНЕННЯ ЇЇ ^{137}CS І ^{90}SR В УМОВАХ МЕДОНОСНИХ УГІДЬ ЛІСОСТЕПУ ТА ПОЛІССЯ

Г. В. Гуцол, О. В. Мазур

Одним із пріоритетних напрямків соціального розвитку України є забезпечення населення високоякісною та безпечною продовольчою сировиною, серед якої високим попитом користується продукція бджільництва, яка містить ряд біологічно активних речовин, а саме вітаміни, вуглеводи, амінокислоти, мінеральні речовини, флавоноїди, меланінів та ін. Переважна частина цих речовин мають високопоживні лікувально-профілактичні властивості, зокрема, імуностимулюючі, радіопротекторні, антиоксидантні, сорбційні та ін. Дані властивості продукції бджільництва забезпечують обумовлений широкий спектр використання її в харчуванні населення та медичній практиці з лікувальною метою.

Відомо, що якість та безпека білкової продукції бджільництва залежать від екологічного стану медоносних угідь. Їх нинішній стан на деяких територіях України зазнав антропогенного забруднення, зокрема радіонуклідами ^{137}Cs і ^{90}Sr внаслідок аварії на Чорнобильській АЕС, що спричинило зниження її якості, ефективності самого виробництва зменшення попиту і використання.

Встановлено, що серед продукції бджільництва, виробленої на забруднених ^{137}Cs (1–5 Кі/км^2) і вище територіях медоносних угідь, квітковий пилок та перга має вищу у декілька разів порівняно з медом та воском, інтенсивність забруднення. Разом із тим виявлено перевищення допустимого рівня радіонуклідів у бджолиному обніжжі та перзі, вироблених на вказаних медоносних угіддях.

Зважаючи на вимоги допустимих рівнів радіонуклідів у продукції бджільництва за ДР-2006, які значно підвищились порівняно з ДР-1991, унаслідок зниження питомої активності ^{137}Cs і ^{90}Sr у бджолиному обніжжі, перзі, гомогенаті трутневих личинок у 3 рази відповідно, виникає потреба у вивченні інтенсивності забруднення вказаної продукції та розробці шляхів підвищення її якості. Необхідність таких досліджень обумовлено соціальним завданням знизити рівень радіаційного пресингу на населення.

Ключові слова: *медоносні угіддя, бджільництво, прополіс, забруднення, бджолине обніжжя, білкова продукція.*

Introduction

Ukraine is one of the world's leading countries with a well-developed beekeeping industry. Over the past 10–15 years, the growth in the number of bee colonies has been driven mainly by the private sector, with 87% of families now keeping bees. According to the Ministry of Statistics of Ukraine, there are currently up to 5.5 million bee colonies in all categories of farms.

The economic importance of beekeeping is determined by providing the population with products such as honey, wax, propolis, bee pollen, feather, royal jelly, bee venom, homogenate, and waste products such as dead bees and bee droppings. Of equal importance is the pollination of crops by bees, which is responsible for 1/3 of the green flora on our planet.

Ukraine is one of the world's five largest honey producers. Annual honey production at apiaries of all categories of farms ranges from 40 to 60 thousand tonnes. Wax production has reached 1.2–1.4 thousand tonnes per year.

Ukraine's forage resources allow it to produce at least 100 thousand tonnes of honey and 1.5–2.0 thousand tonnes of wax.

The production of additional beekeeping products, such as propolis, pollen, royal jelly, drone homogenate, bee venom, which are raw materials for the manufacture of valuable medicinal medicines and food products. However, production of these products is declining due to the lack of a market for them (Butynets, 2005).

Honey is a valuable energy food product with medicinal and dietary properties. It is widely used in the diet of the population for medicinal purposes.

Wax is a raw material for nearly 40 industries, including automotive, electronics, aviation, metallurgy, chemicals, and others. It is used in textile production, paper making, medicine and perfumery.

Due to its antimicrobial effect, propolis is used in medicine to treat wounds, inflammatory and burn processes. Propolis is also widely used in the treatment of infectious diseases.

Bee pollen is used in the food industry. antimicrobial effect, stimulates the body's immune system, and is used for cardiovascular diseases of the stomach and kidneys. In terms of nutritional value, pollen is superior to protein products of plant and animal origin due to the content of amino acids, vitamins, enzymes and is easily absorbed by the human body.

Royal jelly contains enzymes, amino acids, lipids, carbohydrates and other compounds. It strengthens the body, stimulates the cardiovascular and nervous systems and is a raw material for the manufacture of immunostimulant drugs.

Bee venom is recommended for radiculitis, neuralgia, and vascular diseases.

Protein products, in particular bee pollen and feathers, are the main source of food for bees. Protein feed provides bees with amino acids, fat, vitamins, minerals, sugars and other vital biologically active substances. Insufficient supply of protein feed to bee colonies has a negative impact on their development and productivity. It is known that one bee family consumes up to 20 kg of protein feed per season. The excess of the bee colony's need for this feed is used as a marketable product. If bee colonies are sufficiently supplied with honey and pollen plants, an average of 3–4 kg of marketable products can be obtained. The amount of protein feed (bee pollen and pergas) obtained depends on many factors, including the strength of the bee family, the capacity of the honey base, the period and duration of flowering of honey plants, natural and climatic conditions, etc.

In recent years, the apitherapy, food and pharmaceutical industries have begun to use a new non-traditional bee product – a homogenate made from drone larvae. It has antioxidant, immune-modulating, and anti-tumour effects. It further expands the range of applications of bee products as biologically active additives. They are part of apiphytic compositions based on apiary products and medicinal plant materials.

Recently, wax moth preparations have been used for therapeutic purposes, as their immunostimulating and antibacterial properties are superior to chemical and pharmaceuticals (Korbut, 2013).

Beekeeping wastes, in particular, bee slaughter, are widely used in the national economy. It has been proven that substances such as melanin, heparin, and flavonoids isolated from this raw material have high radioprotective, immunostimulating, and sorption properties. Therefore, this raw material is successfully used in foreign countries for the disposal of nuclear waste and for the manufacture of radioprotectors.

Based on these bee products, a new area of medicine has emerged – apitherapy – which aims to study, manufacture and use new medicines using apiary products (Plakhtiy, 2002).

As pollinators, bees are of great benefit to crop production. They pollinate up to 85–90% of entomophilous plants. Bee pollination helps to increase crop yields by 30–60%.

It is difficult to overestimate the environmental importance of beekeeping. Visiting agricultural crops and wild plants, bees ensure their cross-pollination and thus contribute to the pollination of forest, field, garden and meadow entomophilous vegetation. This helps to ensure that plants regenerate.

Material and methods

The study of ^{137}Cs and ^{90}Sr contamination of flower pollen and its processing products (bee pollen, perg and drone larvae homogenate) under conditions of technogenic contamination of honey lands and the impact of agrotechnical measures on the quality of these products was carried out in 2022–2023 in the conditions of honey lands of the Forest-Steppe and Polissya.

The specific activity of ^{137}Cs and ^{90}Sr in the experimental material was determined in the laboratory of the testing centre of the Vinnytsia branch of the State Institution "Institute of Soil Fertility Protection of Ukraine".

The monitoring of radionuclide contamination of bee protein products was carried out from the main agricultural and forest park honey plants. The pollen from these honey plants was used as a raw material for the production of bee protein products, such as bee pollen, pergas and drone larvae homogenate.

Generally accepted methods in ecology and beekeeping were used to monitor ^{137}Cs and ^{90}Sr contamination of protein products.

Soil sampling for radiological studies was carried out using the envelope method at the depth of ploughing.

Four soil samples were taken from each field and sent to the laboratory in plastic bags with labels indicating the number of the original sample, field number, name of the material under study and the place of sampling.

Mineral fertilisers were applied as follows: For corn – nitrogen (ammonium nitrate) in autumn for ploughing and spring cultivation (70%), the rest was used for fertilisation during the growing season at the rate of 100 kg/ha, phosphorus and potash fertilisers were applied in autumn for ploughing, phosphate (simple superphosphate) – 150 kg/ha, potassium (potassium chloride) – 240 kg/ha, for buckwheat – potassium chloride at the rate of 60 kg/ha and for winter rape – potassium chloride at the rate of 90 kg/ha.

The technology of obtaining drone larvae homogenate was carried out according to the method described by (Polishchuk, 2001) which included: preparation of bee colonies, increasing their capacity for rearing drone larvae, selection of drone larvae and their processing (Yarosh, 2005).

The main technological operation in the preparation of bee colonies for the production of drone larvae is the increase of the family strength, which includes the expansion of bee nests.

The following methods were used during the research: field (cultivation of agricultural honey plants, sampling of soils, plants and pollen); radiological (specific activity of ^{137}Cs and ^{90}Sr in protein products of beekeeping); zootechnical (identification of bee breeds, formation of bee colonies based on the principle of analogue groups, accounting of feed stocks, development of bee colonies, their winter hardiness); statistical (mathematical processing of research results); analytical (literature review, generalisation of results and industrial testing) (Polishchuk, 2001; Razanov et al., 2010).

Results

The results of the research on the capacity of the honey base showed that in the conditions of the honey-growing lands of the Forest-Steppe, during the entire active season, 32.7% more commercial bee pollen was produced than in Polissya (Table 1).

On average, during the beekeeping season in the conditions of the studied honey lands of the Forest-Steppe, one bee family produced 2.38 kg of bee pollen, while in Polissya – 1.47 kg.

Table 1

Production of polyfloral bee pollen, kg (n=10)

The number of the bee colony	Honey plants		
	spring	summer	autumn
28	2,3	0,7	-
15	1,2	1,1	
10	2,5	0,5	-
11	1,4	1,0	
23	1,8	0,4	-
7	2,0	0,8	
15	2,7	1,0	-
42	1,1	0,7	
7	1,3	0,6	-
23	1,3	1,1	
41	2,8	0,5	-
25	1,4	0,6	
20	2,9	0,5	-
11	1,6	0,6	
14	2,7	0,8	-
10	1,2	0,6	
19	2,6	0,9	-
9	1,7	1,2	
17	2,2	1,0	-
5	1,8	0,6	
Total	23,8	7,1	-
	14,7	8,6	

*Note: hereinafter *Numerator – Forest-Steppe; *Denominator – Polissya*

In the Forest-Steppe, 77.0% of commercial bee pollen is obtained from spring honey plants, 23.0% – from summer ones. In Polissya, 63.0% of commercial bee pollen is produced from spring honey plants and 37.0% from summer ones.

Comparing the amount of produced bee pollen by harvesting periods during the active bee season, it should be noted that in the Forest-Steppe area, compared to Polissya, 61.9% more was produced from spring honey plants, and 17.5% less from summer ones.

The amount of produced pergue in the conditions of honey lands of the Forest-Steppe was 52.6 % higher compared to the production of similar products in Polissya (Table 2).

On average, over the entire period of the active season, 2.99 kg of bee colony per bee family was produced in the Forest-Steppe, and 1.96 kg in Polissya.

In the conditions of the honey-bearing lands of the Forest-Steppe, 59.0% of the pergas were obtained from spring honey plants, 25.7% – from summer and 15.3% – from autumn. At the same time, in Polissya 68.4% of the perg was produced from spring honey plants and 31.6% from summer ones. It should also be noted that in the conditions of honey-bearing lands of the Forest-Steppe, 31.3% more pergas were produced from spring honey plants and 24.2% more from summer ones compared to the territory of Polissya. From autumn honey plants in the conditions of honey-bearing lands of the Forest-Steppe 15.4% of pergas were obtained, while in Polissya such possibility of obtaining marketable products is absent.

The analysis of the production of drone larvae homogenate showed that in the conditions of the honey lands of the Forest-Steppe it was obtained by 35.1% more compared to the territory of Polissya (Table 3).

On average, 328.3 g of drone larvae homogenate was produced per bee family per

Table 2

Production of pergola, kg (n=10)

The number of the bee colony	**Honey plants**		
	spring	**summer**	**autumn**
21	2,1	1,1	–
17	1,2	0,7	–
52	1,7	0,8	1,1
4	1,3	0,4	–
37	1,8	0,5	–
3	1,1	–	–
54	1,7	0,4	0,8
16	1,4	0,5	–
18	2,0	0,5	0,5
31	1,5	1,1	–
9	2,1	0,7	0,4
33	1,6	0,5	–
11	1,3	1,1	0,5
37	2,1	0,9	–
25	1,2	–	–
27	1,3	0,7	–
57	1,4	1,1	–
29	1,1	0,6	–
8	2,3	1,5	1,3
41	0,8	0,8	–
Total	17,6 13,4	7,7 6,2	4,6 0

Table 3
Production of drone larvae homogenate, kg (n=10)

The number of the bee colony	**Медоноси**		
	spring	**summer**	**autumn**
61	absent	0,277	absent
51		0,170	
62	– // –	0,235	– // –
55		0,230	
66	– // –	0,250	– // –
79		0,340	
67	– // –	0,273	– // –
77		0,280	
93	– // –	0,320	– // –
88		0,310	
94	– // –	0,340	– // –
84		0,270	
95	– // –	450	– // –
63		310	
97	– // –	0,400	– // –
66		0,270	
77	– // –	0,288	– // –
1		0,300	
78	– // –	0,450	– // –
72		0,150	
Total		3,283 2,430	

season in the Forest-Steppe, and 243 g in Polissya.

A more favourable period for the production of drone larvae homogenate, both in the Forest-Steppe and Polissya, was during the flowering of summer honey plants.

The analysis of protein production for the entire season showed that on average, one bee family in the Forest-Steppe produced 32.6% more bee pollen, 29.1% more per bee family and 35.0% more drone larvae homogenate than in Polissya.

The technology for producing bee pollen involves selecting a portion of bee pollen using a pollen trap over a period of time. Some of the flight bees with pollen stay longer near the hives in the area of the working grid, and their injuries can be observed. As a rule, the reaction of bees to a decrease in the supply of pollen to the nests may be accompanied by a decrease in the intensity of brood rearing, which slows down their development and production of marketable products.

In the case of perg production, there is no decrease in the supply of pollen to the nests, and its removal in preserved form is carried out after the end of flowering of the respective types of pollen stalks and sufficient accumulation of this feed in the nest. In this regard, it can be assumed that the production of commercial pergue may have a lesser impact on the development of bee colonies compared to the selection of bee pollen.

The obtained results of the research on the impact of the selection of perg on the development of bee colonies showed that the families from which this product was selected raised more brood than their counterparts involved in the production of bee pollen (Table 4).

In particular, in the Forest-Steppe area, bee colonies from which pergue was produced

Table 4

Development of bee colonies after production of commercial protein products (M±m, n=5)

<table>
<tr><th rowspan="2">Group of bee colonies</th><th rowspan="2">Area.</th><th rowspan="2">Type of products manu-factured</th><th rowspan="2">Bee family number</th><th colspan="3">Brood size, cm²</th><th rowspan="2">Total for the reporting period</th></tr>
<tr><th>03.08.12</th><th>15.08.12</th><th>27.08.12</th></tr>
<tr><td rowspan="5">I</td><td rowspan="12">Forest-steppe</td><td rowspan="6">Bee pollen</td><td>17</td><td>7275</td><td>8375</td><td>6325</td><td>21975</td></tr>
<tr><td>23</td><td>7929</td><td>8457</td><td>6015</td><td>22401</td></tr>
<tr><td>41</td><td>7132</td><td>8112</td><td>5935</td><td>21179</td></tr>
<tr><td>15</td><td>6991</td><td>7830</td><td>6017</td><td>20838</td></tr>
<tr><td>6</td><td>6829</td><td>7970</td><td>6222</td><td>21021</td></tr>
<tr><td>On average for the group</td><td></td><td>7231±
118,9</td><td>8148±
118,5</td><td>6102±
73,0</td><td>21482±
300,5</td></tr>
<tr><td rowspan="5">II</td><td rowspan="6">Perga</td><td>8</td><td>8215</td><td>9250</td><td>7825</td><td>25290</td></tr>
<tr><td>21</td><td>8321</td><td>9371</td><td>7305</td><td>24997</td></tr>
<tr><td>37</td><td>7734</td><td>9218</td><td>6925</td><td>23881</td></tr>
<tr><td>18</td><td>7892</td><td>8791</td><td>7820</td><td>24503</td></tr>
<tr><td>27</td><td>8022</td><td>9305</td><td>7301</td><td>24628</td></tr>
<tr><td>On average for the group</td><td></td><td>8036±
106,1</td><td>9187±
102,3</td><td>7435±
172,5</td><td>24659,4±
239,0***</td></tr>
<tr><td rowspan="5">I</td><td rowspan="12">Polissya</td><td rowspan="6">Bee pollen</td><td>7</td><td>6234</td><td>5157</td><td>4230</td><td>15621</td></tr>
<tr><td>23</td><td>5230</td><td>3232</td><td>2750</td><td>11212</td></tr>
<tr><td>11</td><td>5170</td><td>3125</td><td>2135</td><td>10430</td></tr>
<tr><td>10</td><td>6250</td><td>3075</td><td>1893</td><td>11218</td></tr>
<tr><td>9</td><td>4390</td><td>4174</td><td>2320</td><td>10884</td></tr>
<tr><td>On average for the group</td><td></td><td>5454±
353,9</td><td>3752±
404,5</td><td>2665±
415,4</td><td>11873±
947,9</td></tr>
<tr><td rowspan="5">II</td><td rowspan="6">Perga</td><td>41</td><td>6230</td><td>5035</td><td>3720</td><td>14985</td></tr>
<tr><td>37</td><td>6241</td><td>4831</td><td>2800</td><td>13872</td></tr>
<tr><td>31</td><td>5250</td><td>3178</td><td>3150</td><td>11578</td></tr>
<tr><td>3</td><td>5670</td><td>4032</td><td>3036</td><td>12738</td></tr>
<tr><td>17</td><td>5320</td><td>4930</td><td>2920</td><td>13170</td></tr>
<tr><td>On average for the group</td><td></td><td>5742±
213,6</td><td>4401±
353,4</td><td>3125±
159,7</td><td>13268,6±
568,3***</td></tr>
</table>

reared 14.8% ($p<0.001$) more brood during the accounting period, and in Polissya the number of brood reared increased by 11.8% ($p<0.001$).

In the Forest-Steppe area, bee colonies from which bee pollen was taken reared 9609 cm² or 80.9% more brood compared to Polissya. From the bee colonies involved in the production of commercial pergue, 11390.8 cm² or 46.3% more brood was obtained in the Forest-Steppe area than in the Polissya area.

Thus, the production of perg, provided that it is sufficiently accumulated in the nest of bee colonies, has a lesser impact on the intensity of brood rearing compared to the production of bee pollen.

According to the results of the research on the impact of the production of commercial protein products (bee pollen, perg) on the winter hardiness of bee colonies, it was found that in the Forest-Steppe, bee colonies from which perg was harvested had a 0.8% lower winter mortality rate compared to the colonies involved in the production of bee pollen (Table 5).

The quality of the bee nest, which depends on the number of bee generations reared in the cells and is accompanied by the accumulation of indigestible residues of larval food and cocoons, also had a positive effect on reducing radionuclide contamination of the perg.

In particular, the specific activity of ^{137}Cs and ^{90}Sr in the pergium harvested by bees in combs with up to 5 bee generations was lower than in similar raw materials obtained from combs with 10 to 15 bee generations, by 7.1% and 4.2%, and 9.3 and 11.5%, respectively.

Table 5

Wintering condition of bee colonies (M±m, n=5)

group	Ara	Type of products manu-factured	Bee family number	Strength of bee colonies (number of of hives, pcs.)		Bee flight in winter, %
				before wintering	after wintering	
I	Forest-steppe	Bee pollen	17	7,5	6,5	26,6
			23	6,0	5,5	8,3
			41	8,0	7,5	12,5
			15	7,5	7,0	6,7
			6	6,0	5,0	16,6
On average for the group				7,0±0,41	6,3±0,41	10,0±3,56
II		Perga	8	6,5	6,0	9,1
			21	8,0	7,0	12,5
			37	7,5	7,0	6,6
			18	7,5	6,5	13,3
			27	7,0	7,0	7,0
On average for the group				7,3±0,25	6,7±0,19	9,1±1,38
I	Polissya	Bee pollen	7	6,5	5,5	23,0
			23	5,5	4,5	18,2
			11	7,0	6,0	14,3
			10	7,5	6,0	33,3
			9	5,5	5,0	18,2
On average for the group				6,4±0,40	5,4±0,27	15,6±3,28
II		Perga	41	4,5	4,0	11,1
			37	8,0	7,5	6,2
			31	7,5	7,5	0
			3	6,5	4,5	31,0
			17	5,0	4,5	10,0
On average for the group				6,3±0,68	5,6±0,78	11,1±5,2

Discussion

Summarising the results of the research in this subsection, it should be noted that the most attractive for the production of protein bee products is perg, the production of which has a less negative impact on the vital activity of bee families, in particular on development and winter hardiness.

The use of our improved technology for the production of pergas makes it possible to improve their quality.

As a result of the Chornobyl accident, radioactive contamination in some areas of Ukraine has created certain problems in agricultural production, including beekeeping.

The accident contaminated about 53.5 thousand km^2 of Ukraine's territory. The radioactive contamination also affected honey-growing areas, which are a source of flower pollen from which bees produce protein products, including bee pollen, bee royal jelly and other products. These products are widely used by the population due to their nutritional and medicinal properties. The use of bee products in public nutrition and medical practice requires careful attention to their quality, which is subject to continuously increasing requirements. The data on permissible levels (2006) of specific activity of ^{137}Cs and ^{90}Sr in bee products, including protein products, have decreased three times compared to the 1991 levels. Therefore, the migration of radionuclides in the system soil → crop products → bee products requires constant monitoring.

The migration processes of radionuclides in the soil → plant → crop products system depend on many factors, including the type, level of moisture, intensity of contamination, soil acidity, presence of micro- and macroelements, plant species, etc.

When describing the literature data on the state of soils of honey-growing lands in the studied areas of the Forest-Steppe and Polissya, it is necessary to note some differences and peculiarities of their contamination with radioactive substances.

Thus, the honey-growing lands of Polissya are located mainly on sod-podzolic soils, the total area of which is up to 60%, the largest share of which is occupied by slightly and medium podzolic soils – up to 92%. The humus content in these soils is between 1.0 and 2.0%, and the soil pH is between 5 and 5.6. In addition, Polissia's honey-growing lands have sod-podzolic soils with a humus content of 0.9 to 1.9%, which are very poor in nitrogen, phosphorus, potassium and trace elements. These soils have a salt extract pH of 4.2 to 5.2. There is also a small amount of alkaline soils and soils of highland and surface bogs on the territory of Polissya honey lands. It should also be noted that 50% of the soils in Polissya's honey-growing areas are excessively moist. This type of soil is classified as low-fertility. Thus, the soils of Polissya's honey lands are characterised by low humus and trace elements with high acidity and moisture levels, which can be favourable conditions for increasing radionuclide translocation to plants and their products, in particular, pollen and products of its processing by bees.

The analysis of ^{137}Cs contamination of soils of honey-bearing lands in the studied territories of Polissia showed an excess of permissible levels by 2.1 to 3.2 times. The specific activity of ^{90}Sr in some soils of honey plants in the studied areas was 1.9 times lower than the permissible levels, and in some areas, on the contrary, it was up to 3.8 times higher. That is, there is a variation in the contamination of honey plants with radioactive substances in this area.

The honey-growing lands of the Forest-Steppe have grey forest soils, podzolised chernozems, typical chernozems and others, which have a higher humus content compared to Polissia. In particular, the humus content in chernozem can range from 3 and above, the pH of the salt extract is from 4.8 to 6.8, and they have moderate moisture content.

In the studied soils of the Forest-Steppe, the specific activity of radionuclides was below the permissible levels, in particular, ^{137}Cs from 2.8 to 5.5 times, and ^{90}Sr from 16.6 to 24.5 times.

Thus, the literature shows that the soils in the studied areas of the honey-growing areas of the Forest-Steppe and Polissya have significant differences in terms of ^{137}Cs and ^{90}Sr contamination, as well as chemical and physical properties, which may have a certain impact on the intensity of contamination of bee protein products.

When analysing the intensity of radionuclide contamination of honey lands in the studied areas, it should be noted that in Polissia, the specific activity of ^{137}Cs and ^{90}Sr in the soil of honey lands was 5.0 and 5.0 times higher than in the Forest-Steppe, respectively.

The soils of Polissya honey lands contained ^{137}Cs 5.0 Ci/km^2 and ^{90}Sr 0.05 Ci/km^2, while in the Forest-Steppe zone – 1.0 Ci/km^2 and 0.01 Ci/km^2, respectively.

The obtained results of studies on specific activity of radionuclides in the honeycomb also indicate a tendency to seasonality of its harvesting by bees and the level of contamination of honey plants (Table 6).

Thus, the specific activity of ^{137}Cs in the spring honey extracted in the Forest-Steppe was 3.8 % and 13.5 % lower, respectively, compared to similar raw materials obtained from pollen of summer and autumn honey plants. In Polissya, the specific activity of ^{137}Cs in spring honeybee pollen was 1.0% lower than in summer and 4.5% lower than in autumn.

The specific activity of ^{90}Sr in the bee pollen from spring honey plants in the Forest-Steppe was 8.9 and 12.1% lower than in similar products obtained from summer and autumn honey plants, respectively.

The specific activity of ^{90}Sr in the pollen obtained in Polissya from spring honey

Table 6

Specific activity of radionuclides in polyfloral wax, Bq/kg (M±m, n=4)

Production	**^{137}Cs**		**^{90}Sr**	
	Forest-steppe	**Polissya**	**Forest-steppe**	**Polissya**
The feathers of spring honey plants	7,7±0,108	153,8±0,091	0,51±0,009	10,3±0,147
The feathers of summer honey plants	8,0±0,091	155,3±0,129	0,56±0,009	12,3±0,129
The pergas of autumn honey plants	8,9±0,108	161,1±0,070	0,58±0,009	15,7±0,091

plants was lower than in similar raw materials obtained from summer honey plants by 16.3% and autumn honey plants by 34.4%.

A significant difference was found between the specific activity of radionuclides in the perga harvested from spring, summer and autumn honey plants in the Forest-Steppe and Polissya regions. The specific activity of ^{137}Cs in bees' pollen from summer honey plants in Polissya was 20.0 times higher, in summer – 19.4 times higher, in autumn – 18.1 times higher compared to similar products obtained from the honey plants of the Forest-Steppe. The specific activity of ^{90}Sr in the bee-derived pollen produced in Polissia was 20.2, 21.9 and 27.1 times higher in spring, summer and autumn honey plants, respectively, compared to similar products produced in the Forest-Steppe. In other words, the specific activity of ^{137}Cs and ^{90}Sr in the honeycomb also depended on the intensity of soil contamination of honeybee lands.

The analysis of radionuclide contamination of pergia showed that the specific activity of ^{137}Cs and ^{90}Sr in this product harvested in Polissia was 45.6 times and 11.3 times higher, respectively, compared to similar products harvested in the Forest-Steppe.

At the same time, it should be noted that in the Forest-Steppe, the specific activity of ^{137}Cs and ^{90}Sr in the pepper was 9.3 and 89.3 times lower than the permissible levels (2006), respectively. In Polissia, the specific activity of ^{137}Cs was 4.9 times higher than the permissible levels, and ^{90}Sr, on the contrary, was 7.9 times lower.

It was found that in the territory of the forest-steppe honey lands, the specific activity of ^{137}Cs compared to ^{90}Sr was 38.4 times higher in pepper, and 154.8 times higher in Polissya. At the same time, it was found that an increase in the specific activity of ^{137}Cs and ^{90}Sr in soil by 8.4 and 8.6 times, respectively, was accompanied by an increase in radionuclides in pergium by 45.5 and 11.4 times, respectively.

The specific activity of ^{137}Cs and ^{90}Sr in drone larvae homogenate produced by bee colonies in Polissia was 14.7 and 4.1 times higher, respectively, compared to similar products from the Forest-Steppe area.

The specific activity of ^{90}Sr in the pollen produced from the pollen of the Forest-Steppe honey plants was 10.0% higher than in the bee pollen and 5.5 times higher than in the drone larvae homogenate.

The specific activity of ^{90}Sr in the perga produced on the territory of Polissya honey lands was 19.9% higher compared to bee pollen and 20.2 times higher compared to drone larvae homogenate.

In other words, 26 years after the Chornobyl accident, only ^{137}Cs was exceeded (in 2006) in bee pollen and bee feathers produced by bees in some honey-growing areas of Polissya, where this radionuclide exceeded 4 Ci/km^2 in soil. At the same time, it is necessary to note contamination of protein products with ^{137}Cs and ^{90}Sr, depending on the level of contamination of honey lands with its type and type of radionuclides, and the period of harvesting.

In particular, an increase in the level of radionuclide contamination of honeybee soils leads to an increase in the intensity of ^{137}Cs and ^{90}Sr accumulation in bee pollen, pergola and drone larvae homogenate. The higher intensity of ^{137}Cs and ^{90}Sr contamination is characterised by protein products produced by bees from autumn honey plants, and the lower intensity – from spring ones. Among the protein products of beekeeping, the highest specific activity of ^{137}Cs and ^{90}Sr was in the feathers, and the lowest was in the homogenate of drone larvae. The specific activity of ^{137}Cs was higher in bee leg, perg and drone larvae homogenate compared to ^{90}Sr.

Conclusions

1. The specific activity of ^{137}Cs in bee protein products for the 26-year period after the Chornobyl accident exceeded the permissible standards (DR-2006) only in the territories of honey lands with the level of contamination with this isotope exceeding 4 Ci/km^2.

2. Specific activity of ^{137}Cs and ^{90}Sr in bee pollen, pergium and drone larvae homogenate depended on the intensity of honey plantations contamination, type of products and period of their harvesting. The highest specific activity of ^{137}Cs and ^{90}Sr was characterised by the feather, and the lowest – by the drone larvae homogenate. A relatively higher specific activity of ^{137}Cs and ^{90}Sr was detected in bee pollen, feather and drone larvae homogenate during the flowering period of autumn honey plants, and a relatively lower activity in summer and spring honey plants.

3. Reducing the soil acidity of honey plants from 4.6 to 5.8 and from 6.6 to 7.7 reduced the accumulation coefficient in flower pollen of ^{137}Cs by 42.8 % and 50 %, ^{90}Sr by 16.6 and 50 %, respectively.

Recommendations. On the territories of honey-bearing lands with soil concentrations of ^{137}Cs up to 1 Ci/km^2, the production of bee pollen, pergue and drone larvae homogenate can be carried out without restrictions.

Under conditions of soil contamination of honey-bearing lands with ^{137}Cs in the range of 1–4 Ci/km^2, bee pollen production should be carried out under radiological control and with the use of potassium chloride fertilisation and liming of acidic soils during the cultivation of agricultural honey plants.

Production of bee pollen, pergola and drone larvae homogenate under conditions of ^{137}Cs contamination of honey lands above 4 Ci/km^2 should be carried out from pollen of tree honey plants (small-leaved and broad-leaved linden, white acacia, apple, pear and maple), with mandatory radiological control and use of these products for beekeeping needs, in particular for the production of bee feed.

To reduce ^{137}Cs and ^{90}Sr contamination of pergue in the technological processes of its production, an additional operation should be introduced, the essence of which is to remove the honey cover by drying the honeycomb by bees.

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