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EFFECT OF DIFFERENT DOSES OF GE CITRATE AND PROBIOTIC *LACTOBACILLUS CASEI* B-7280 ON THE PHOSPHOLIPID COMPOSITION OF BEES TISSUES

Aim. *To investigate changes in the phospholipid composition of bee body tissues under the influence of the lyophilized probiotic strain Lactobacillus casei IMV B-7280 in combination with nanotechnological Ge citrate in laboratory conditions.* ***Methods.*** *The research was conducted on honey bees of the Carpathian breed. Bees of the control group were fed with 60% sugar syrup in the amount of 1 cm^3/group/day. Experimental 1 group of bees (E 1), in addition to 1 cm^3 of sugar syrup, received 0.1 μg of Ge in the form of nanotechnological citrate and a solution of the probiotic L. casei B-7280 at a concentration of 10^6 CFU/cm^3; experimental group 2 of bees (E 2), in addition to 1 cm^3 of sugar syrup, received 0.2 μg of Ge in the form of citrate and L. casei B-7280 at a concentration of 10^6 CFU/cm^3. Drinking sugar syrup, Ge citrate, and probiotics lasted 34 days. In the preparatory period and at the end of the experimental period, live bees were selected from the control and experimental groups for physiological and biochemical studies to determine the content of total phospholipids and the ratios of their classes in tissue homogenates of the entire organism. The content of total phospholipids was determined by the amount of inorganic phosphorus in the lipid extract. Thin-layer chromatography on silica gel was used to separate phospholipids. Rf values identified individual phospholipids. Quantitative analysis of phospholipid subclasses was performed using the TotalLab software, which was expressed as a percentage of total content.* ***Results.*** *The research results showed that in the homogenates of bee body tissues in the research groups, an increase*

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in the content of total phospholipids was established relative to the preparatory period. In the fractional composition of phospholipids, an increase in the content of phosphatidylethanolamine and phosphatidylcholine was established in the tissues of bees of groups E 1 and E 2 concerning the preparatory period. An increase in the content of phosphatidylethanolamine and phosphatidylcholine and a decrease in phosphatidylinositol in body tissue lipids of group E 2 compared to the control group were noted. A decrease in the content of phosphatidylinositol in the tissues of group E 2 bees relative to the preparatory period was also established. The content of sphingomyelin and lysophosphatidylcholine decreased in tissue lipids of bees of groups E 1 and E 2 as compared to the preparatory period. The use of lactobacillus casei strain B-7280 and Ge citrate led to an increase in the number of lactobacilli and bifidobacteria in both parts of the intestine, as well as to a decrease in the number of staphylococci, streptococci, and microscopic fungi. ***Conclusions.*** *Nanotechnological Ge citrate and probiotic L.casei in the applied doses under the conditions of their feeding with sugar syrup in a laboratory thermostat for 34 days show a dose-dependent biological effect on honey bees by increasing the content of total phospholipids and changing the ratios of individual subclasses of phospholipids. However, it also indicates a shift in the spectrum of different fractions of phospholipids to a decrease in the content of hard-to-oxidize lysophosphatidylcholine and sphingomyelin while increasing easy-to-oxidize phosphatidylcholine and phosphatidylethanolamine, which may indicate stabilization of compensatory mechanisms for supporting cell membranes. The use of Lactobacillus casei B-7280 and Ge citrate for feeding bees under the conditions of the laboratory thermostat led to quantitative changes in the composition of the intestinal microbiota of bees, in particular to an increase in the number of lactic acid bacteria and bifidobacteria, as well as a decrease in the number of some other groups of microorganisms in the intestine.*

Keywords: *honey bees, body tissues, nanotechnological Ge citrate, probiotic, phospholipids.*

The honey bee (*Apis mellifera*) is an essential agricultural pollinator of entomophilous crops, increasing their yield. However, factors of biotic, abiotic, and anthropogenic origin disrupt physiological processes in the bee body, suppressing their resistance, immunity, and metabolism (Ptaszyńska et al., 2018; Neov et al., 2019; Almasri et al., 2021). Therefore, modern beekeeping creates the necessary conditions to increase bee viability, health, productivity, and reproduction (Hrechka & Senchylo, 2022).

In the domestic and foreign practice of beekeeping, artificial feeding of bees is used with new effective means of natural origin and certain mineral elements as metabolic stimulants of organic and inorganic origin. These substances and compounds added in different doses to feeding can affect physiological and biochemical processes and increase the productivity and resistance of honey bees (Dvylyuk & Kovalchuk, 2017; Romaniv et al., 2018; Tauber et al., 2019).

Preparations of natural origin can avoid many negative phenomena since their mechanism of action activates the body's natural protective properties. Probiotic preparations in beekeeping, which hurt pathogenic microflora and promote the development of beneficial microflora in bees' gastrointestinal tracts, are relevant in this direction.

The gut microbiota of honey bees consists of 8—10 bacteria genera, which comprise more than 97% of the entire community (Kwong & Moran, 2016). Most bacterial genera include closely related species with a high level of strain diversity, the most common of which are genera of lactic acid bacteria Lactobacillus (Bombilactobacillus) (Zheng et al., 2020), as well as Gilliamella, Snodgrassella, and Bifidobacterium. Bee gut bacteria are adapted to their diverse food niches, play an essential role in digestive processes, and are beneficial for the host's lipid and mineral nutrition, immune homeostasis, and resistance to pathogens (Zheng et al., 2018; Kovalshuk et al., 2021; Lazarenko et al., 2021). A recent study found that oral supplementation with bee gut Lactobacillus increased hemolymph glycerophospholipids and improved memory in bumblebees (Li et al., 2021).

At the same time, it has been proven that the vitality and resistance of the honey bee organism largely depend on mineral nutrition, which affects metabolic processes at the level of tissues, organs, and systems (Dvylyuk & Kovalchuk, 2017; Kovalchuk et al., 2020). The use of biotic

trace elements in bee feeding as highly active compounds produced by nanotechnology participate in protein, lipid, carbohydrate, and mineral metabolism, activate enzyme systems, etc. (Kovalchuk et al., 2014; Dvylyuk & Kovalchuk, 2017; Cho et al., 2020).

The influence of various amounts of mineral and organic compounds obtained based on nanotechnological citrates on the metabolic processes of the bees' bodies was clarified. Several works were published based on the research results (Kovalchuk et al., 2014; Dvylyuk & Kovalchuk, 2017). A higher biological efficiency of adding nanocarboxylates of biotic elements than their mineral salts in bee feeding was established (Kovalchuk et al., 2021).

Adding some aspects to bee feed as metabolic stimulators introduced in different doses affects the correction of physiological and biochemical processes and increases their productivity and resistance (Dvylyuk & Kovalchuk, 2017). Such mineral components include Co, Ge, Se, Cr, Ni, and others. The indicated results, as well as previous studies of the IBT of NAS of Ukraine using citrates of certain microelements and probiotics (Romaniv et al., 2018; Kovalchuk et al., 2019), provide a theoretical basis for the development of new nano- and biotechnological means and drugs to increase the resistance and reproduction of bees. However, the biological effect of the newly synthesized nanotechnological Ge citrate mineral complex in combination with probiotic preparations of the *L. casei* B-7280 class has not been studied to date.

In connection with the earlier research, the **purpose** of this work was to study the influence of the lyophilized probiotic strain *Lactobacillus casei* IMV B-7280 in combination with nanotechnological Ge citrate on changes in the phospholipid composition of bee body tissues in laboratory conditions.

Materials and Methods. *Experimenting.* The research was conducted on the Carpathian breed honey bees from the laboratory apiary-vivarium of the Institute of Animal Biology of NAS of Ukraine. Lyophilized probiotic strain *Lactobacillus casei* IMV B-7280 was used in the research. This strain was isolated in the Department of Problems of Interferon and Immunomodulators of D.K. Zabolotny Institute of Microbiology and Virology of NAS of Ukraine (IMV) from the associated culture of biological material and deposited in the Ukrainian collection of microorganisms of the IMV. Before each experiment, the viability of the lyophilized strains was checked by monitoring their growth on Mann-Rogose-Sharpe (MRSA) medium at 37 °C for 24—48 h.

The research was conducted under laboratory thermostat conditions on three bee colonies similar in weight, colony strength, and queen age. 50—60 bees were selected and formed into three groups. Bees of the control and research groups were kept in cages-containers with a volume of 4 dm^3 in similar conditions to a TS-80M-3 laboratory thermostat with micro ventilation at 30 °C and humidity of 74—76%.

Bees of the control group (C) were grouped by feeding with 60% sugar syrup (SS) in the amount of 1 cm^3/group/day. Experimental group 1 of bees (E 1), in addition to 1 cm^3 of sugar syrup, received 0.1 μg of Ge in the form of nanotechnological citrate (NTC) (Kosinov & Kaplunenko, 2009) and a solution of the probiotic *L. casei* B -7280 at a concentration of 10^6 CFU/cm^3; experimental group 2 of bees (E 2), in addition to 1 cm^3 of sugar syrup, received 0.2 μg of Ge in the form of citrate and immunobiotic *L. casei* B-7280 at a concentration of 10^6 CFU/cm^3.

Drinking SS, Ge citrate, and probiotics took 34 days. During the preparatory period and on the 34th day of the experimental period, live bees were selected from the control and experimental groups for physiological and biochemical studies to determine the content of total phospholipids and the ratio of their classes in tissue homogenates of the entire organism.

Homogenized tissue (1g) was extracted with 20 cm^3 of a mixture of chloroform-methanol in a ratio of 2:1 (v/v) according to Folch's method

(Folch et al., 1957). The mixture was filtered through a deashed filter, a blue band. 4 cm^3 of an aqueous solution of 0.74% KCl was added to each sample of lipid extract. After 24 hours, the upper phase containing hydrophobic peptides was removed with a water pump, and the lower phase containing lipids was used in further studies.

The content of total phospholipids was determined by the amount of inorganic phosphorus in the lipid extract, as described in (Vaskovsky et al., 1975), and their mass was calculated in mg/g of tissue.

Separation of phospholipids. To separate phospholipids by one-dimensional thin-layer chromatography on silica gel (L 5/40μ, LSL 5/40μ, Chemapol, Czech Republic), a solvent system of chloroform—methanol-water in the ratio 65:25:4 (v/v/v) was used (Kates, 1986). Crystalline iodine vapor was used as a developer. The developed plates were scanned on HP Deskjet 2050 (China). The identification of individual subclasses of phospholipids was carried out using Rf values. Phospholipid subclasses were quantified using the TotalLab TL120 software (Nonlinear Dynamics Limited, UK) and expressed as a percentage of total content.

Study of the spectrum of the intestinal microbiome. To determine the qualitative and quantitative spectra of the intestinal microbiota of bees, on the 34th day, the midgut and hindgut (separately) were taken from the bees of either experimental group. The obtained samples were placed in microtubes of the «Eppendorf» type, weighed, filled with 1 mL of physiological solution, and homogenized in a sterile mortar with sterile sand. The resulting suspension was diluted to concentrations of 10^{-5} and 10^{-7} through a series of tenfold dilutions with sterile 0.15 M NaCl, and 100 μL was taken for vaccination of solid selective nutrient media for the cultivation of various groups of microorganisms:

- meat-peptone agar (MPA) — a medium for isolation and cultivation of aerobic and facultatively anaerobic microorganisms;
- BAIRD-PARKER-Agar («Merck,» Germany) — a selective medium for the isolation of staphylococci;
- KF-Streptococcus agar («Merck,» Germany) — a selective medium for isolation of streptococci;
- Man-Rogosa-Sharpe agar (MRSA, HiMedia, India) — a selective medium for isolation of lactobacilli;
- Bifidum agar (BA, HiMedia, India) — a selective medium for isolation of bifidobacteria;
- ENDO (HiMedia, India) — a selective medium for isolation of coliform bacteria;
- Saburo (HiMedia, India) — a selective medium for isolation of microscopic fungi;
- Pseudomonas agar (HiMedia, India) — a selective medium for isolation of pseudomonads.

Plates were incubated under appropriate conditions, and colonies of typical morphology were counted for each group of microorganisms. The data were expressed as Lg colony-forming units (CFU) in 1 mg of the studied sample.

The research was conducted following the «General Ethical Principles of Animal Experiments» (VII National Congress of Bioethics, Kyiv, 2019) and the European Convention on the Protection of Animals Used for Experimental and Other Scientific Purposes (Strasbourg, 1986).

Statistical analysis. All obtained digital data were processed using the STATISTICA computer program, which used variational statistics, and the Excel program from Microsoft Office in 2007 and 2010. Numerical data are presented as arithmetic mean (M) and standard error (± m). Differences between groups were considered statistically significant at $p < 0.05$.

Results. Phospholipids take an active part in the formation of the lipid bilayer of biomembranes, affect the biochemical mechanisms of temperature adaptation, maintain the microviscosity of membranes, including several metabolic functions, in particular, enzyme catalysis reactions, ion transport, and intracellular signaling, and they are also involved in receptor-mediated

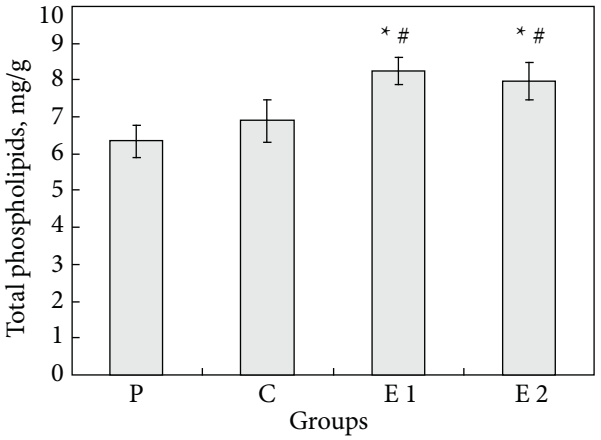

Fig. 1. The content of total phospholipids in the body tissues of bees: P — preparatory period, C — control group, E 1 — first experimental group, E 2 — second experimental group. * $p<0.05$ — probable differences between the preparatory and experimental periods by groups; # $p<0.05$ — probable differences between the control and experimental groups

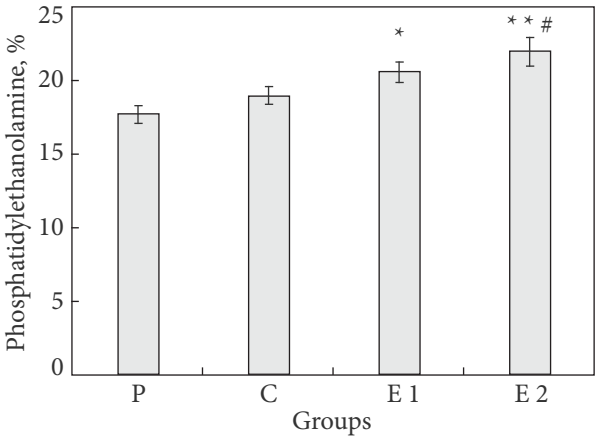

Fig. 2. The content of phosphatidylethanolamine in homogenates of bee body tissues (%, M±m, n=5): P — preparatory period, C — control group, E 1 — first experimental group, E 2 — second experimental group. * $p<0.05$; ** $p<0.01$ — probable differences between the preparatory and experimental periods by groups; # $p<0.05$ — probable differences between control and experimental groups

endocytosis of food components in the animal body (Romaniv et al., 2018; Li et al., 2021; Dai et al, 2021). In the homogenates of bee body tissues, an increase in the content of total phospholipids in E 1 and E 2 groups was found, respectively, by 30.28% ($p<0.01$) and 25.87% ($p<0.05$) compared to the preparatory period (Fig. 1).

In the subclasses of phospholipids, 17.66—21.90% of phosphotidylethanolamine (PhEA), 12.23—14.96% of phosphatidylinositol (PhI), 23.79—28.45% of phosphatidylcholine (PhH), 14.66—15.24% of phosphatidylserine (PhS), and 11.84—15.78% of sphingomyelin (SM) were found along with 10.65 —13.68% of lysophosphatidylcholine (LFH). In the fractional composition of phospholipids, an increase in the content of phosphatidylethanolamine was established in bees of groups E 1 and E 2 by 16.14% ($P<0.05$) and 24.01% ($P<0.01$) concerning the preparatory period, and group E 2 by 15.69% ($P<0.05$) compared to the control group (Fig. 2).

A decrease in the content of phosphatidylinositol was established in group E 2 by 11.70% ($p<0.05$) before the preparatory period and by

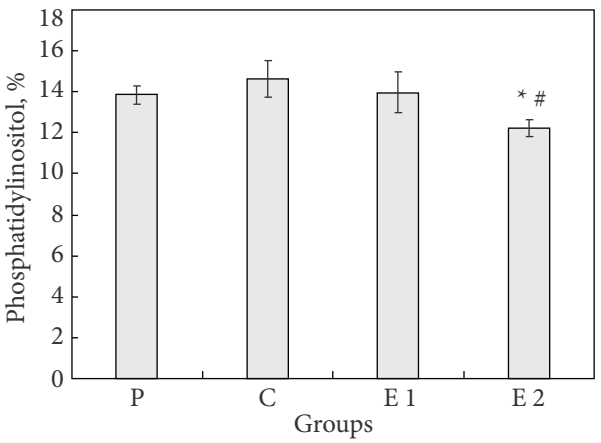

Fig. 3. The content of phosphatidylinositol in homogenates of bee body tissues (%, M±m, n=5). P — preparatory period, C — control group, E 1 — first experimental group, E 2 — second experimental group. * $p<0.05$ — probable differences between the preparatory and experimental periods by groups; # $p<0.05$ — probable differences between control and experimental groups

16.40% ($p<0.05$) compared to the control group of bees (Fig. 3).

An increase in phosphatidylcholine was observed in bees of the E 1 and E 2 groups by

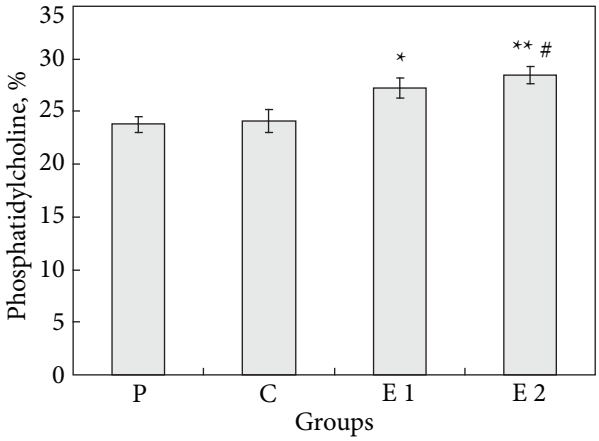

Fig. 4. The content of phosphatidylcholine in homogenates of bee body tissues (%, M±m, n=5). P — preparatory period, C — control group, E 1 — first experimental group, E 2 — second experimental group. * p<0.05; ** p<0.01 — probable differences between the preparatory and experimental periods by groups; # p<0.05 — probable differences between control and experimental groups

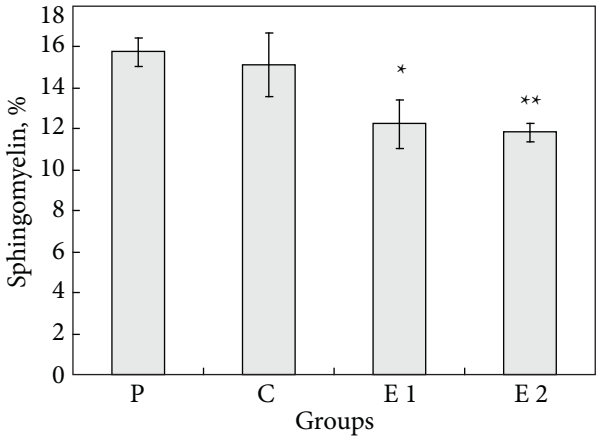

Fig. 5. The content of sphingomyelin in homogenates of bee body tissues (%, M±m, n=5). P — preparatory period, C — control group, E 1 — first experimental group, E 2 — second experimental group. * p<0.05; ** p<0.01 — probable differences between the preparatory and experimental periods by groups.

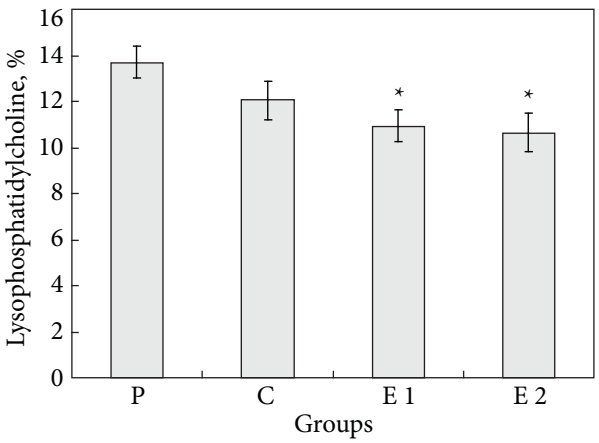

Fig. 6. The content of lysophosphatidylcholine in homogenates of bee body tissues (%, M±m, n=5). P — preparatory period, C — control group, E 1 — first experimental group, E 2 — second experimental group. * p<0.05 — probable differences between the preparatory and experimental periods by groups

14.54% (p<0.05) and 19.59% (p<0.01) according to the preparatory period and by 18.15% (P<0.05) in E 2 compared to the control group (Fig. 4).

The content of sphingomyelin decreased in the bees of groups E 1 and E 2 by 22.37% (p<0.05) and 24.97% (p<0.01) compared to the preparatory period (Fig. 5).

A decrease in the content of lysophosphatidylcholine in the bees of groups E 1 and E 2 was established to be by 20.10% and 22.15% (p<0.05) compared to the preparatory period (Fig. 6).

As for phosphatidylserine, its content in the body tissues of bees had no significant changes in the experimental groups compared to the preparatory period and the control group of bees, and its differences are improbable.

In the midgut of bees, aerobic and facultatively anaerobic microorganisms decreased only in group E2, whereas staphylococci decreased separately in both experimental groups (Table 1).

On the 34th day of the experiment, the number of streptococci and coliform bacteria in the midgut of bees remained at the control level in both experimental groups.

Microscopic fungi and pseudomonads were utterly eliminated from the midgut of bees for 34 days under the conditions of application of *L. casei* IMV B-7280 in the amount of 10^6 CFU + Ge in the form of citrate.

On the 34th day of the study, both experimental groups exhibited an increase in the number of lactobacilli and bifidobacteria in the midgut of bees.

In the hindgut, the number of aerobic and facultatively anaerobic microorganisms and staphylococci was lower than in the control in both experimental groups (Table 2). In contrast, streptococci and coliform bacteria remained at the control level on day 34 in E 1 and E 2.

We also noted that in the hindgut of bees that received supplementary feeding in the form of 60% sugar syrup 1 mL/group/day + *L. casei* IMV B-7280 in the amount of 10^6 CFU + 0.1 μg of Ge in the form of citrate for 34 days (E 1), the number of microscopic fungi and pseudomonads decreased significantly. On the other hand, in E 2, which received the double dose of Ge in the form of citrate for 34 days, these opportunistic microorganisms were eliminated, which may indicate a possible direct or indirect antimicrobial effect of Ge citrate.

After 34 days of the experiment, the number of lactobacilli and bifidobacteria in the hindgut of bees that received the probiotic strain *L. casei* IMV B-7280 and Ge citrate was higher.

Discussion. Cell membrane lipids, mainly phospholipids, form a bilayer that acts as a barrier between the cell and the environment and between different cell organelles. Numerous studies show that the lipid bilayer not only functions as a structural barrier but also plays a crucial role in the regulation of many cellular processes due to the diversity of membrane lipids (Wu et al., 2016; Sunshine & Iruela-Arispe, 2017; Harayama & Riezman, 2018). Analysis of the obtained data shows that the addition of different doses of nanotechnological Ge citrate and the probiotic strain *L.*

Table 1. **Spectrum of midgut microbiota of bees fed with *L. casei* strain IMV B-7280 and Ge citrate**

Group	The number of microorganisms sown on nutrient media (Lg CFU/mg)							
	MPA	BAIRD-PARKER-Agar	KF-Streptococcus agar	ENDO	Saburo	Pseudomonas agar	MRSA	BA
Control	4.12 ± 0.12	3.55 ± 0.09	3.14 ± 0.04	3.86 ± 0.14	3.27 ± 0.21	2.95 ± 0.02*	2.83 ± 0.09	2.37 ±0.05
Group E 1	3.72 ± 0.06	2.18 ± 0.04**	3.10 ± 0.07	4.25 ±0.15	0**	0**	4.12 ± 0.04**	3.17 ± 0.03**
Group E 2	3.12 ± 0.04*	2.06 ± 0.06**	2.87 ± 0.11	4.11 ±0.21	0**	0**	3.98 ± 0.08**	3.22 ± 0.02**

*p < 0.05; **p < 0.01 compared to control

Table 2. **Spectrum of hindgut microbiota of bees fed with *L. casei* strain IMV B-7280 and Ge citrate**

Group	The number of microorganisms sown on nutrient media (Lg CFU/mg)							
	MPA	BAIRD-PARKER-Agar	KF-Streptococcus agar	ENDO	Saburo	Pseudomonas agar	MRSA	BA
Control	4.93 ± 0.05	4.18 ± 0.04	3.27 ± 0.05	4.51 ± 0.07	3.78 ± 0.04*	4.66 ± 0.08*	3.52 ± 0.09	3.12 ± 0.11
Group E1	4.01 ± 0.06*	2.33 ± 0.05**	2.99 ± 0.17	4.65 ± 0.14	1.55 ± 0.09**	1.20 ± 0.12**	5.78 ± 0.05**	4.62 ± 0.06**
Group E2	3.55 ± 0.03**	2.12 ± 0.08**	3.17 ± 0.08	4.87 ± 0.10	0**	0**	5.06 ± 0.10**	4.33 ± 0.04**

*p < 0.05; **p < 0.01 compared to control

casei B-7280 to sugar syrup affected both the total content of phospholipids (Fig. 1) and the ratio of their subclasses. An increase in the content of total phospholipids in the tissues of bees of groups E 1 and E 2 compared to the control group and the preparatory period may indicate the stimulating effect of the probiotic *L. casei* in combination with NTC Ge on the synthesis of these lipids in the body of bees and their adaptive capacity.

Phosphatidylethanolamine (PhEA) is one of the most common phospholipids in the body. It is part of the cell membrane and contains many unsaturated fatty acids, a source of their active metabolites. PhEA is involved in signal transduction as a substrate of phospholipase D (Braun et al., 2016) of the ethanolamine component of glycosylphosphatidylinositol anchors that bind to proteins on the surface of the cell membrane and perform a signaling function (Dai et al., 2021).

The determined increase in the content of PhEA (Fig. 2) can be interpreted as maintaining its homeostasis and inhibiting phospholipase D in the body of bees under the action of the probiotic *L. casei* in combination with the applied doses of Ge citrate. Some studies have shown that increasing the content of PhEA by adding its precursor ethanolamine to food or overexpressing the phosphatidyl biosynthetic enzymes phosphatidylserine decarboxylase (PSD) extends the lifespan of yeast organisms as well as insects and mammals (Rockenfeller et al., 2015; Dai et al., 2021). The lifespan extension effect of PhEA is associated with an increase in the autophagic flux (Rockenfeller et al., 2015), a positive regulator of lifespan in many studied organisms (Hansen et al., 2018). It has been suggested that adding PhEA may increase lifespan by promoting autophagy. In addition, reducing PhEA by inhibiting PSD encourages the production of reactive oxygen species (ROS) and accelerates aging in yeast (Rockenfeller et al., 2015). The link between PhEA and ROS is also supported by *C. elegans* studies showing that PhEA supplementation increases the resistance to oxidative stress and promotes longevity via DAF-16 (Park et al., 2021). These studies suggest that PhEA plays a crucial role in prolonging life by acting as a regulator of ROS production. Therefore, PSD-mediated synthesis of PhEA, which occurs in the mitochondrial inner membrane, is essential for the electron transport chain activity (Calzada et al., 2019). Thus, it can be assumed that the increase in the content of PhEA in the body of bees of the experimental groups when the *L. casei* probiotic is added to the SS in combination with the applied doses of Ge citrate causes the activation of mitochondria and, accordingly, affects the life span.

Phosphatidylinositol is a smaller fraction of cellular phospholipids than PhEA. Still, it controls almost all aspects of cell life and death and is a crucial signaling element in the cells of living organisms. It can be hydrolyzed to release 1,2-diacylglycerol and inositol-1,4,5-triphosphate, which in animal cells lead to activation of protein kinase C and cellular calcium mobilization, respectively. Under the action of probiotic *L. casei* and Ge citrate in a dose of 0.2 μg, a decrease in the content of PHI was observed in group E 2 (Fig. 3). It is known that phosphoinositols are involved in signal transduction processes and are a source of such vital messengers as diacylglycerol, inositol phosphates, and arachidonic acid (Dickson & Hille, 2019; Blunsom & Cockcroft, 2020). Based on the above, the detected changes in the content of phosphatidylinositol can be explained by the inhibition of the activity of phospholipase C. The basis of the changes may be a decrease in the rate of receptor-mediated hydrolysis of phosphatidylinositol by phospholipase C (Blunsom & Cockcroft, 2020). The reduction in the content of PhI in the phospholipids of group E 2 may be a consequence of the activation of phospholipase C by Ge ions as a specific adaptive response to the action of this element.

The determined increase in the content of phosphatidylcholine (Fig. 4) in the lipids of bee tissues under the action of the probiotic *L. casei* IMV B-7280 in combination with Ge citrate may

be due to the effect on the inhibition of phospholipase D. This enzyme catalyzes its hydrolysis with the formation of phosphatidic acid. PhH homeostasis is critical for organelle functions, while its reduction shows cellular stress, known as lipid bilayer stress (Halbleib et al., 2017; Shyu et al., 2019). Thus, the cell develops an adaptive mechanism whereby the loss of PhH affects multiple cellular processes through the stress response (Koh et al., 2018; Ho et al., 2020). Furthermore, an increase in PhH may prolong the bees' life span. Some studies report changes in PhH content with animal age, taking into account species and tissue specificity. Thus, PhH content is markedly reduced in old nematodes (Gao et al., 2017; Wan et al., 2019) and shows a significant decrease in the kidneys of old mice (Braun et al., 2016). This also applies to humans, as PhH content is higher in centenarians than in the elderly (Montoliu et al., 2014).

Shingomyelin (ceramide) is an essential structural component of biological membranes and one of the endpoints of sphingolipid synthesis. Along with phosphatidylcholine, CM is one of the most common phospholipids in biological membranes. Structural diversity and cellular topology allow ceramide to exert multiple effects and be metabolized into other bioactive sphingolipids. Some diseases (cancer, inflammation, atherosclerosis, diabetes, and some rare diseases) involve the sphingomyelin cycle in the body. The type and composition of sphingolipids modulate the biophysical properties of membranes, which can be organized into two-dimensional domains. Membrane properties determined by the specific type and amount of sphingolipids allow biological membranes to adapt to temperature, pH, and membrane tension (Sessa et al., 2021; Trenti et al., 2022). For example, the presence of SM increases the stiffness and compactness of the plasma membrane (PM). In mammalian membranes, CMs with different acyl chains, unsaturated phospholipids, and cholesterol can be used by the cell to improve the lateral structure of membranes (Sessa et al., 2021).

Lysophosphatidylcholine is a phospholipid component of oxidized low-density lipoproteins (Ox-LDL). This subclass of phospholipids originates from the cleavage of phosphatidylcholine by phospholipase A 2 and is catabolized to other substances by various enzymatic pathways. LPHH exerts pleiotropic effects mediated by its receptors, G protein-coupled signaling receptors, Toll-like receptors, and ion channels to activate multiple secondary messengers (Law et al., 2019; Ren et al., 2022). The established reduction of LPHH (Fig. 6) in the body of bees of groups E 1 and E 2 under the action of probiotic *L. casei* B-7280 in combination with different doses of Ge citrate compared to the control group can be explained by the inhibitory effect phospholipase A 2 on the cleavage of phosphatidylcholine.

Phosphatidylserine is one of the main phospholipids, which has the biochemical properties of an anionic phospholipid, binds to various proteins, and participates in many biological processes, such as enzyme activation, apoptosis, neurotransmission, and synaptic contraction (Ma et al., 2022).

PhS is formed by the exchange of head groups in the mammalian body cells with the help of PhS synthases; for example, PhS synthase 1 is responsible for the exchange of headgroup choline with PhH, and PhS synthase 2 is responsible for the exchange of headgroup ethanolamine with PhEA. Since PhS synthases 1 and 2 are regulated in the mitochondrial-associated membranes (MAMs) of the endoplasmic reticulum, PhS is produced in the endoplasmic reticulum and transported to the mitochondria or Golgi via the MAMs (Ma et al., 2022). In mitochondria, part of PhS is catalyzed to PhEA by PhS decarboxylase in the inner mitochondrial leaflet, while the other part of PhS is incorporated into the mitochondrial membrane. Under normal conditions, PhS is found exclusively in the cytoplasm of the plasma membrane, endoplasmic reticulum lumen, Golgi, mitochondria, and endosomes to support normal organelle function

(Kay & Fairn, 2019). It is located on the inner surface of the plasma membrane to maintain regular cellular activity. Flip-flopping of PhS to the outer surface of the bilayer can trigger apoptosis (Kiraz et al., 2016; Chua et al., 2019). Thus, adding Ge SS citrate and probiotic *L. casei* to the feed did not affect the relative content of PhS, which means the violation of asymmetry is essential in the functioning of membrane-bound enzyme systems.

In general, the detected changes in the lipid composition of the cell membranes of the body tissues of bees when the probiotic *L. casei* IMV B-7280 was added to the sugar syrup in combination with different doses of NTC Ge may be a consequence of their multifactorial influence on the structure and function of individual tissues and organs.

Also, the shift in the spectrum of different fractions of phospholipids toward smaller contents of difficult-to-oxidize lysophosphatidylcholine and sphingomyelin with increasing easy-to-oxidize phosphatidylcholine and phosphatidylethanolamine may indicate the stabilization of compensatory mechanisms for supporting cell membranes.

As known, the interaction between microbiota and bee organism is common among pollinating insects. The gut microbiome of the honey bee actively participates in protection against infections and degradation of pollen coat polysaccharides, as well as in the detoxification of pollutants and toxic plant compounds. In addition, the honey bee microbiome is essential for honey production and Perga during maturation (Tsadila et al., 2023).

In bees, the symbiotic intestinal microflora is essential not only for digestion but also for the antagonistic activity against pathogenic microorganisms and the functioning of the body's immune system. Probiotic supplementation is essential when bees limit contact with the environment and natural probiotic bacteria (Fedoruk et al., 2023).

Using *Lactobacillus casei* strain B-7280 and Ge citrate increased the number of lactobacilli and bifidobacteria in both parts of the intestine and decreased the number of staphylococci, streptococci, and microscopic fungi.

Thus, it can be considered appropriate to continue research on probiotic lactobacilli strains to create a complex preparation with Ge citrate to increase bees' life expectancy and honey productivity. This preparation will also support the homeostasis of their microbiome, which will provide natural protection for the bees' bodies and maintain homeostasis.

Conclusions. 1. In the doses applied, nanotechnological Ge citrate and *L.casei* show a dose-dependent biological effect on honey bees fed SS in a laboratory thermostat for 34 days.

2. The use of NTC Ge and *L. casei* in the feeding of bees leads to an increase in the absolute content of total phospholipids ($p<0.05$) in the body of bees under the action of 0.1 and 0.2 μg of Ge compared to the preparatory period and the control group, which may be due to the influence of these additives on the level of the ratio of individual subclasses of phospholipids.

3. Supplementation of bees with NTC Ge at 0.1 and 0.2 μg/mL SS and 10^6 CFU/mL SS *L. casei* was characterized by differences in the distribution of individual classes of phospholipids in bee tissue homogenates with a higher relative content of phosphatidylethanolamines and phosphatidylcholines and a lower content of sphingomyelin and lysophosphatidylcholine in groups E1 and E2 compared to the control group, but a higher content of phosphatidylethanolamines and phosphatidylcholines and a lower content of phosphatidylinositols in group E2 bees concerning the preparatory period, which indicates a dose-dependent effect of these additives on the metabolism of lipids and their fractions.

4. The use of *Lactobacillus casei* B-7280 and Ge citrate for feeding bees under the conditions of a laboratory thermostat led to quantitative

changes in the composition of the intestinal microbiota of bees, in particular, an increase in the number of lactic acid bacteria and bifidobacteria and a decrease in the number of some other groups of microorganisms in the intestine.

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Compliance with ethical principles. None of the experiments described in this article involved using vertebrate animals.

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REFERENCES

Almasri, H., Tavares, D. A., Diogon, M., Pioz, M., Alamil, M., Sené, D., Tchamitchian, S., Cousin, M., Brunet, J. L., & Belzunces, L. P. (2021). Physiological effects of the interaction between Nosema ceranae and sequential and overlapping exposure to glyphosate and difenoconazole in the honey bee *Apis mellifera*. *Ecotoxicol Environ Saf, 217*, 112258.

Blunsom, N. J., & Cockcroft, S. (2020). CDP-Diacylglycerol Synthases (CDS): Gateway to Phosphatidylinositol and Cardiolipin Synthesis. *Front Cell Dev Biol, 8*, 63.

Braun, F., Rinschen, M. M., Bartels, V., Frommolt, P., Habermann, B., Hoeijmakers, J. H., Schumacher, B., Dollé, M. E., Müller, R. U., Benzing, T., Schermer, B., & Kurschat, C. E. (2016). Altered lipid metabolism in the aging kidney identified by three layered omic analysis. *Aging, 8*(3), 441—457.

Calzada, E., Avery, E., Sam, P. N., Modak, A., Wang, C., McCaffery, J. M., Han, X., Alder, N. N., & Claypool, S. M. (2019). Phosphatidylethanolamine made in the inner mitochondrial membrane is essential for yeast cytochrome bc_1 complex function. *Nature communications, 10*(1), 1432.

Cho, J. M., Chae, J., Jeong, S. R., Moon, M. J., Shin, D. Y., & Lee, J. H. (2020). Immune activation of Bio-Germanium in a randomized, double-blind, placebo-controlled clinical trial with 130 human subjects. Therapeutic opportunities from new insights. *PLoS ONE, 15*(10), e0240358.

Chua, B. A., Ngo, J. A., Situ, K., & Morizono, K. (2019). Roles of phosphatidylserine exposed on the viral envelope and cell membrane in HIV-1 replication. *Cell Commun Signal, 17*, 132.

Dai, Y., Tang, H., & Pang, S. (2021). The Crucial Roles of Phospholipids in Aging and Lifespan Regulation. *Front Physiol, 12*, 7775648.

Dickson, E. J., & Hille, B. (2019). Understanding phosphoinositides: rare, dynamic, and essential membrane phospholipids. *Biochem J, 476*(1), 1—23.

Dvylyuk, I. I., & Kovalchuk, I. I. (2017). Reproductive ability of bee queens at the conditions of feeding citrates of Argentum and Cuprum. *The Animal Biology, 19*(2), 30—36. [In Ukrainian].

Fedoruk, R. S., Kovalchuk, I. I., Mezentseva, L. M., Tesarivska, U. I., Pylypets, A. Z., & Kaplunenko, V. H. (2022). Germanium compounds and their role in animal body. *The Animal Biology, 24*(1), 50—60. [In Ukrainian].

Fedoruk, R. S., Kovalchuk, I. I., Pylypets, A. Z., Tsap, M. M., Lesyk, Y. V., Androshulik, R. L., Demchenko, O. A., Tymoshok, N. O., & Babenko, L. P. (2023). The effect of probiotic microorganisms on catalase activity, fractional composition of soluble proteins, and intestinal microbiota of honey bees. *Mikrobiol Z, 85*(4), 46—57.

Folch, J., Lees, M., & Stanley, G. H. (1957). A simple method for the isolation and purification of total lipids from animal tissues. *Journal of Biological Chemistry 226*(1), 497—509.

Gao, A. W., Chatzispyrou, I. A., Kamble, R., Liu, Y. J., Herzog, K., Smith, R. L., van Lenthe, H., Vervaart, M. A. T., van Cruchten, A., Luyf, A. C., van Kampen, A., Pras-Raves, M. L., Vaz, F. M., & Houtkooper, R. H. (2017). A sensitive mass spectrometry platform identifies metabolic changes of life history traits in *C. elegans*. *Scientific reports, 7*(1), 2408.

Halbleib, K., Pesek, K., Covino, R., Hofbauer, H. F., Wunnicke, D., Hänelt, I., Hummer, G., & Ernst, R. (2017). Activation of the unfolded protein response by lipid bilayer stress. *Molecular Cell, 67*(4), 673—684.e8.

Hansen, M., Rubinsztein, D. C., & Walker, D. W. (2018). Autophagy as a promoter of longevity: insights from model organisms. *Molecular cell biology, 19*(9), 579—593.

Harayama, T., & Riezman, H. (2018). Understanding the diversity of membrane lipid composition. Nature reviews. *Molecular cell biology, 19*(5), 281—296.

Ho, N., Yap, W. S., Xu, J., Wu, H., Koh, J. H., Goh, W. W. B., George, B., Chong, S. C., Taubert, S., & Thibault, G. (2020). Stress sensor Ire1 deploys a divergent transcriptional program in response to lipid bilayer stress. *The Journal of cell biology, 219*(7), e201909165.

Hrechka, H., & Senchylo, O. (2022). Winter hardiness of Ukrainian bees of intrabreed type «Gadyatsky». *Scientific and Production Journal «Beekeeping of Ukraine», 1*(8), 14—18. [In Ukrainian].

Kates, M. (1986). Techniques in Lipidology: Isolation Analysis and Identification of Lipids, second ed., Elsevier Press, Amsterdam, The Netherlands.

Kiraz, Y., Adan, A., Kartal Yandim, M., & Baran, Y. (2016). Major apoptotic mechanisms and genes involved in apoptosis. *Tumour Biol, 37*(7), 8471—8486.

Koh, J. H., Wang, L., Beaudoin-Chabot, C., & Thibault, G. (2018). Lipid bilayer stress-activated IRE-1 modulates autophagy during endoplasmic reticulum stress. *J Cell Sci, 131*(22), jcs217992.

Kosinov, M. V., & Kaplunenko, V. G. (2009). Pat. 38391 UA, ICP C 07C 51/41 Method for metal carboxylates obtaining. Nanotechnology of obtaining metal carboxylates. Publ 12.01.2009; Bull № 1. [In Ukrainian].

Kovalchuk, I. I., Fedoruk, R. S., Rivis, Y. F., & Romaniv, L. I. (2014). Influence of Germanium and Selenium on lipid and fatty acid composition of body tissues melliferous bees and ambrosia for feeding nanoaquacitrates germanium and selenium. Scientific and technical bulletin of the State Research Control Institute of Veterinary Medicines and Feed Additives and the Institute of Animal Biology, 15(1, 2), 31–36. [In Ukrainian].

Kovalchuk, I. I., Kykish, I. B., & Kaplunenko, V. H. (2020). Influence of citrate microelements on the reproductive capacity of queen bees. Actual problems of natural sciences: modern scientific discussions: Collective monograph. Riga, Latvia: «Baltija Publishing», 87—110.

Kovalchuk, I. I., Fedoruk, R. S., Spivak, M. Ya., Romanovych, M. M., & Iskra, R. Ya. (2021). *Lactobacillus casei* IMV B-7280 immunobiotic strain influence on the viability of honey bees and the content of microelements in the organism. *Mikrobiol Z, 83*(2), 42—50.

Kwong, W. K., & Moran, N. A. (2016). Gut microbial communities of social bees. *Nat Rev Microbiol, 14*, 374—384.

Law, S-H., Chan, M-L., Marathe, G. K., Parveen, F., Chen, C-H., & Ke, L-Y. (2019). An Updated Review of Lysophosphatidylcholine Metabolism in Human Diseases. *International Journal of Molecular Sciences, 20*(5), 1149.

Lazarenko, L. M., Babenko, L. P., Gichka, S. G., Sakhno, L. O., Demchenko, O. M., Bubnov, R. V., Sichel, L. M., & Spivak, M. Ya. (2021). Assessment of the Safety of *Lactobacillus casei* IMV B-7280 Probiotic Strain on a Mouse Model. *Probiotics Antimicrob Proteins, 13*(6), 1644—1657.

Li, L., Solvi, C., Zhang, F., Qi, Zh., Chittka, L., & Zhao, W. (2021). Gut microbiome drives individual memory variation in bumblebees. *Nat Commun, 12*, 6588.

Ma, X., Li, X., Wang, W., Zhang, M., Yang, B., & Miao, Z. (2022). Phosphatidylserine, inflammation, and central nervous system diseases. *Front Aging Neurosci, 14*, 975176.

Montoliu, I., Scherer, M., Beguelin, F., DaSilva, L., Mari, D., Salvioli, S., Martin, F. P., Capri, M., Bucci, L., Ostan, R., Garagnani, P., Monti, D., Biagi, E., Brigidi, P., Kussmann, M., Rezzi, S., Franceschi, C., & Collino, S. (2014). Serum profiling of healthy aging identifies phospho- and sphingolipid species as markers of human longevity. *Aging, 6*(1), 9—25.

Neov, B., Georgieva, A., Shumkova, R., Radoslavov, G., & Hristov, P. (2019). Biotic and Abiotic Factors Associated with Colonies Mortalities of Managed Honey Bee (*Apis mellifera*). *Diversity, 11*(12), 237.

Park, S., Kim, B., & Park, S. (2021). Supplementation with phosphatidylethanolamine confers anti-oxidant and anti-aging effects via hormesis and reduced insulin / IGF-1-like signaling in *C. elegans*. *Mech Ageing Dev, 197*, 111498.

Petrovska, I. R., Salyha, Y. T., & Vudmaska, I. V. (2022). Statistical Methods in Biological Research. A monograph. Kyiv, Ahrarna Nauka, 172 p. [In Ukrainian].

Ptaszyńska, A. A., Gancarz, M., Hurd, P. J., Borsuk, G., Wiącek, D., Nawrocka, A., Strachecka, A., Załuski, D., & Paleolog, J. (2018). Changes in the bioelement content of summer and winter western honeybees (*Apis mellifera*) induced by *Nosema ceranae* infection. *PLoS ONE, 13*(7), e0200410.

Ren, J., Lin, J., Yu, L., & Yan, M. (2022). Lysophosphatidylcholine: Potential Target for the Treatment of Chronic Pain. *International Journal of Molecular Sciences, 23*(15), 8274.

Rockenfeller, P., Koska, M., Pietrocola, F., Minois, N., Knittelfelder, O., Sica, V., Franz, J., Carmona-Gutierrez, D., Kroemer, G., & Madeo, F. (2015). Phosphatidylethanolamine positively regulates autophagy and longevity. *Cell death and differentiation, 22*(3), 499—508.

Romaniv, L. I., Kovalchuk, I. I., Pashchenko, A. G., & Fedoruk, R. S. (2018). Content of lipids in tissues of the melliferous bees additional fed with soybean meal, sugar syrup and citrates of Co and Ni. *Bìol Tvarin, 20*(3), 84—92. [In Ukrainian].

Sessa, L., Nardiello, A. M., Santoro, J., Concilio, S., & Piotto, S. (2021). Hydroxylated Fatty Acids: The Role of the Sphingomyelin Synthase and the Origin of Selectivity. *Membranes, 11*(10), 787.

Shyu, P. Jr., Ng, B. S. H., Ho, N., Chaw, R., Seah, Y. L., Marvalim, C., & Thibault, G. (2019). Membrane phospholipid alteration causes chronic ER stress through early degradation of homeostatic ER-resident proteins. *Scientific reports, 9*(1), 8637.

Sunshine, H., & Iruela-Arispe, M. L. (2017). Membrane lipids and cell signaling. *Current opinion in lipidology, 28*(5), 408—413.

Tauber, J. P., Collins, W. R., Schwarz, R. S., Chen, Y., Grubbs, K., Huang, Q., Lopez, D., Peterson, R., & Evans, J. D. (2019). Natural product medicines for honey bees: Perspective and protocols. *Insects, 10*, 356.

Trenti, F., Sandron, T., Guella, G., & Lencioni, V. (2022). Insect cold-tolerance and lipidome: Membrane lipid composition of two chironomid species differently adapted to cold. *Cryobiology, 106*, 84—90.

Tsadila, C., Amoroso, C., & Mossialos, D. (2023). Microbial Diversity in Bee Species and Bee Products: Pseudomonads Contribution to Bee Well-Being and the Biological Activity Exerted by Honey Bee Products: A Narrative Review. *Diversity, 15*(10), 1088.

Vaskovsky, V. E., Kostetsky, E. Y., & Vasenden, I. M. (1975). A universal reagent for phospholipid analysis. *Journal of Chromatography A, 114*(1), 129—141.

Wan, Q. L., Yang, Z. L., Zhou, X. G., Ding, A. J., Pu, Y. Z., Luo, H. R., & Wu, G. S. (2019). The Effects of Age and Reproduction on the Lipidome of *Caenorhabditis elegans*. *Oxidative medicine and cellular longevity, 4*, 1—14.

Wu, W., Shi, X., & Xu, C. (2016). Regulation of T cell signalling by membrane lipids. Nature reviews. *Immunology, 16*(11), 690—701.

Zheng, H., Steele, M. I., Leonard, S. P., Motta, E. V. S., & Moran, N. A. (2018). Honey bees as models for gut microbiota research. *Lab Anim, 47*, 317—325.

Zheng, J., Wittouck, S., Salvetti, E., Franz, C. M. A. P., Harris, H. M. B., Mattarelli, P., O'Toole, P. W., Pot, B., Vandamme, P., Walter, J., Watanabe, K., Wuyts, S., Felis, G. E., Gänzle, M. G., & Lebeer, S. (2020). A taxonomic note on the genus Lactobacillus: Description of 23 novel genera, emended description of the genus Lactobacillus Beijerinck 1901, and union of Lactobacillaceae and Leuconostocaceae. *Int J Syst Evol Microbiol, 70*(4), 2782—2858.

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ВПЛИВ РІЗНИХ ДОЗ GE ЦИТРАТУ ТА ПРОБІОТИКА *LACTOBACILLUS CASEI* B-7280 НА ФОСФОЛІПІДНИЙ СКЛАД ТКАНИН ОРГАНІЗМУ БДЖІЛ

Мета. Дослідити в лабораторних умовах зміни фосфоліпідного складу тканин організму бджіл за впливу ліофілізованого пробіотичного штаму *Lactobacillus casei* IMV B-7280 у поєднанні з нанотехнологічним Ge цитратом. **Методи.** Дослідження проведено на медоносних бджолах карпатської породи. Бджоли контрольної групи отримували підгодівлю з 60 % цукрового сиропу в кількості 1 см^3/групу/добу. Експериментальна група бджіл 1 (Е 1), додатково до 1 см^3 цукрового сиропу, отримувала 0,1 мкг Ge у вигляді нанотехнологічного цитрату і розчин пробіотика *L. casei* B-7280 у концентрації 10^6 КУО/см^3; експериментальна група Е 2 — додатково до 1 см^3 цукрового сиропу додавали 0,2 мкг Ge у вигляді цитрату і *L. casei* B-7280 у концентрації 10^6 КУО/см^3. Тривалість випоювання цукрового сиропу, Ge цитрату та пробіотика — 34 дні. У підготовчий період і із завершенням дослідного періоду з контрольної та експериментальних груп відбирали живих бджіл для проведення фізіолого-біохімічних досліджень з визначенням вмісту загальних фосфоліпідів і співвідношення їх класів у гомогенатах тканин всього організму. Вміст загальних фосфоліпідів визначали за кількістю неорганічного фосфору в ліпідному екстракті. Для розділення фосфоліпідів використовували тонкошарову хроматографію на силікагелі. Ідентифікацію окремих фосфоліпідів проводили за величинами Rf. Кількісний аналіз підкласів фосфоліпідів проводили за допомогою програмного забезпечення TotalLab і виражали у відсотках від загального вмісту. **Результати.** Результати досліджень показали, що в гомогенатах тканин організму бджіл збільшується вміст загальних фосфоліпідів порівняно до підготовчого періоду. У фракційному складі фосфоліпідів встановлено збільшення вмісту фосфатидилетаноламіну і фосфатидилхоліну у тканинах бджіл груп Е 1 та Е 2 відносно підготовчого періоду. Відзначено збільшення вмісту фосфатидилетаноламіну і фосфатидилхоліну та зменшення фосфатидилінозитолу у ліпідах тканин організму Е 2 групи порівняно до контрольної групи. Також встановлено зменшення вмісту фосфатидилінозитолу у тканинах бджіл Е 2 групи відносно підготовчого періоду. Вміст сфінгомієліну і лізофосфатидилхоліну зменшувався у ліпідах тканин бджіл Е 1 та Е 2 груп відносно підготовчого періоду. Застосування штаму *Lactobacillus casei* B-7280 і цитрату Ge приводило до збільшення кількості лактобацил та біфідобактерій в обох відділах кишківника, а також до зниження кількості стафілококів, стрептококів та мікроскопічних грибів. **Висновки.** Нанотехнологічний цитрат Ge і пробіотик *L. casei* у застосованих дозах за умов підгодівлі їх цукровим сиропом у лабораторному термостаті впродовж 34 діб виявляють дозозалежну біологічну дію в медоносних бджіл підвищенням вмісту загальних фосфоліпідів і змінами співвідношення окремих підкласів фосфоліпідів. Проте також вказує на зміщення спектра різних фракцій фосфоліпідів до зменшення вмісту вжкоокиснюваних (лізофосфатидилхоліну та сфінгомієліну) зі збільшенням легкоокиснюваних (фосфатидилхоліну, фосфатидилетаноламіну), що може свідчити про стабілізацію компенсаторних механізмів підтримки клітинних мембран. Застосування *Lactobacillus casei* B-7280 і цитрату Ge для підгодівлі бджіл за умов лабораторного термостату приводило до кількісних змін у складі кишкової мікробіоти бджіл, зокрема до збільшення кількості молочнокислих бактерій та біфідобактерій, а також зменшення кількості деяких інших груп мікроорганізмів в кишківнику.

Ключові слова: *медоносні бджоли, тканини організму, Ge цитрат нанотехнологічний, пробіотик, фосфоліпіди.*