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EFFICACY OF PROBIOTICS IN LIVESTOCK

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INTRODUCTION

In the dynamic conditions of animal husbandry development, new feed additives, preventive and therapeutic agents are increasingly being introduced and used to increase the productivity and resistance of animals to diseases of various etiologies[1]. Special attention is paid to the fight against opportunistic gastrointestinal infections[2].

When organizing animal feeding, it is important to take into account the risk of microbial contamination of feed and objects in the surrounding environment, which leads to the preemptive colonization of the intestines of newborn animals by pathogenic microorganisms, and as a result, significantly slows down and hinders the formation of normal intestinal microflora[3]. In addition, this causes a disturbance in wall digestion, metabolism, a decrease in resistance and productivity of animals, and the development of gastrointestinal diseases, especially in young animals. The use of antibiotics in these cases is not always justified, as they have a destructive effect on pathogenic microorganisms and the normal microflora of the intestine. The normal functioning of the intestine in animals and birds can be maintained only by maintaining the balance of natural gastrointestinal microflora[4].

Over the past two decades, there has been a sharp increase in interest in biological preparations that positively affect animal health due to the presence of stabilized cultures of symbiotic living microorganisms or their fermentation products – probiotics[5].

The term «probiotic» was first used by F. Vergio in 1954, where the author, in a comparative aspect, pointed out the harmful effects that occur after taking antibiotics and the positive effect of beneficial bacteria, calling them «probiotics» The word «probiotic» is of Greek origin: pro – for, bios – life,

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meaning «for life»[6]. According to F. Vergio's definition, probiotics are a mixed culture of bacteria that have a beneficial effect on the body and improve intestinal microflora[7].

In 1965, D.M. Lilly and R.H. Stilwell used the term «probiotic» to designate pharmacological preparations containing a culture of normal microflora that positively affects the microbial composition of the intestines and the host organism[8].

In 1974, L. Richard and R. Parker gave a positive characterization not only to living microorganisms but also to the products of their fermentation in their scientific work and pointed out their antagonism towards pathogenic microflora[9].

According to the definitions formulated by R. Fuller (1989), probiotics are bacteria that are cultured in laboratory conditions and then used to restore the balance of microflora, which can be altered by stress, illness, or the use of antibiotics or antibacterial agents[10].

Probiotics are substances of microbial or non-microbial origin that, when introduced naturally, promote homeostasis by normalizing the microflora in the bodies of animals[11]. They help maintain a balanced gut microflora at an optimal level and correct it, activate cellular and humoral immunity, accelerate animal adaptation to concentrated feeding, and improve nutrient absorption[12].

A probiotic effect is achieved thanks to their multi-component composition (amino acids, vitamins, enzymes, and other biologically active substances) and diverse pharmacological activity. However, many of the mechanisms of probiotic action remain unclear and are the subject of research by many scientists around the world[13].

Today, probiotic feed additives are used to stimulate non-specific immunity, prevent and treat various etiologies of gastrointestinal infections,

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and for digestive disorders caused by sudden changes in diet, disrupted feeding regimes, and dysbiosis.

1. Theoretical and practical rationale for the use of probiotics

As mentioned above, veterinary probiotics are feed additives consisting of microbial and non-microbial substances, which positively affect the growth and development of the indigenous microbiota of the gastrointestinal tract of animals by optimizing it and increasing the metabolic and protective mechanisms of the animal's body. Probiotics mainly consist of live microorganisms, usually representatives of the normal intestinal microflora, which possess a probiotic effect and have a negative impact on the growth and development of pathogenic and conditionally pathogenic microflora of the intestine[14].

Currently, there is a large number of veterinary probiotic feed additives on the market based on probiotic strains of normal intestinal microflora of animals. These preparations mainly include strains of lactobacilli, bifidobacteria, a complex of lyophilized spore-forming bacteria Bacillus subtilis, Bacillus coagulans, Clostridium butyricum, sorbents, etc[15]. Although the bacteria Bacillus subtilis and Bacillus licheniformis are not classical representatives of the normal flora of the intestines of animals and birds, they have properties that allow the body to maintain microbial balance at a naturally ecological level[16].

Also, it should be taken into account that most scientists cannot provide a clear definition of the term «normal microflora.» This is due to the fact that normal microflora in the human or animal body is represented by evolutionarily formed complex microbiocenoses that exist as multifunctional systems[17].

The quantitative and species composition of the intestinal microflora is formed from the first days of postnatal development of the organism. According to H. Tissier (1905), the gastrointestinal tract remains sterile on the first day after birth. In the first week, cocci, bacilli, and Escherichia coli begin to proliferate in the digestive tube. Subsequently, the so-called «transplantation period» begins, when bifidobacteria begin to displace all

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previous microorganisms, and the normal intestinal flora is formed, which at this stage consists mainly of bifidobacteria[18].

The composition of the microflora in different sections of the gastrointestinal tract varies, which is due to the anatomical and functional peculiarities of each of the sections, as well as depending on the type of feeding (diet) of the animals. The microflora of the stomach is characterized by weak species variability and number due to the acidic environment and the effect of lysozyme, which has bactericidal properties. The stomach's flora consists mainly of acid-resistant microorganisms and representatives of anaerobes. In the proximal sections of the intestine, the chyme has a weakly alkaline reaction, and free molecular oxygen is present in the lumen of the intestines, which is a favorable environment for the growth and development of aerobic groups of microorganisms[19]. However, in the small intestine of clinically healthy animals, the flora is not diverse and consists of lactobacilli, cocci, fungi, and to a lesser extent, bacilli. In the duodenum and jejunum, microorganisms are mainly located along the wall. In the distal sections of the intestine, the oxygen level drops sharply, so only anaerobic microorganisms can reproduce and live there, the groups of which are characterized by significant variability. An intermediate link among aerobic and anaerobic microorganisms inhabiting the intestine is occupied by facultative microorganisms[20].

The microflora of the gastrointestinal tract is a necessary component for both the functioning of the digestive system and the overall health of the macroorganism. Microorganisms can adhere to the mucous membrane of the intestine and, together with the mucus produced by goblet cells, form a biofilm that serves as a barrier against the attachment and penetration of foreign bodies through the mucous membrane[21].

The microbial ecosystem of the digestive system indirectly participates in the stimulation of the motility of the gastrointestinal tract and counteracts the proliferation of pathogenic microflora by synthesizing hormones and producing formic, acetic, and lactic acid[22]. The intestinal flora partially

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performs the function of digestion, which is due to the synthesis of digestive enzymes for the breakdown of food particles. The composition of the microflora changes under the influence of probiotic preparations, with an increase in the number of lactobacilli and other anaerobic microorganisms[23].

Mestecky (2015) reported that the microflora of the intestine stimulates the proliferation of enterocytes, increasing the overall area of the intestine[24].

Probiotic strains of microorganisms possess bacteriocinogenic activity, which is characterized by the synthesis of proteinaceous antibiotics with a limited range of action that destroy pathogenic species or strains or inhibit their growth. The protective functions of the indigenous microflora of the intestine also include the synthesis and maintenance of a certain level of secretory IgA on the mucous membrane and regulation of the maturation of the lymphoid apparatus of the intestine. Secretory IgA is capable of binding to pathogenic microorganisms and other antigens, hindering their attachment to enterocytes of the mucous membrane of the intestine. Epithelial cells bind to IgA through specific receptors and play a crucial role in the selective transport of immunoglobulins into the lumen of the intestine[25].

It is important to remember that in order to restore normal intestinal microflora, it is necessary to first eliminate the cause that negatively affects the balance of microbiota. In animals and birds with dysbiosis, diarrhea, decreased digestion, and absorption of nutrients are observed. The microorganisms that are part of probiotic preparations, if used as a therapeutic agent, have virtually no chance of performing their functions. In the gastrointestinal tract, there are no conditions for the attachment and growth of probiotic bacteria at that moment. Therefore, it is necessary to first carry out therapeutic and preventive measures to improve the body's condition to stabilize digestion before using probiotics[26].

However, the obstacle to the implementation of probiotic feed additives in the technology of raising young animals and birds is the fact that industry experts are accustomed to the use of feed antibiotics and do not want to give them up in favor of new forms of probiotics. Also, a significant barrier in this direction is such precedents when probiotic preparations are unable to provide the efficiency declared by manufacturers when applied to a particular type of animal or bird, which discourages specialists from giving up feed antibiotics in favor of probiotics. However, the low efficiency of probiotics is often due

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to the distributor's failure to adhere to strict temperature storage conditions for feed additives based on lactobacilli and bifidobacteria, which serves as a contributing factor to the reduction of live microflora[27]. Nevertheless, probiotics based on Bacillus subtilis bacteria have minimal environmental impact factors because a significant portion of microbial cells in such preparations are represented by spores. Therefore, spore-forming probiotics are currently more effective compared to preparations based on lacto– and bifidobacteria[28].

Progressive forms of probiotic preparations contain natural sorbents (charcoal, zeolites, silicas, diatomites) in their composition. Microorganisms in such preparations are immobilized on micro-particles of the sorbent and, thanks to chemical and electrostatic forces, interact with the intestinal wall better, and colonization by microorganisms occurs faster. Additionally, the sorbent performs a detoxification function[29].

Prominent representatives of fourth-generation probiotics are Probion-forte (Woogene B&G, Korea) and BioPlus 2B (Biochem, Germany), which include immobilized live bacteria Bacillus coagulans, Bacillus subtilis, Clostridium butyricum, Rhodopseudomonas capsulata, Bacillus subtilis, and Bacillus licheniformis at a concentration of 3.2 × 109 CFU/g of feedstuff[30].

Bacterial probiotic preparations have a complex effect on the animal organism and are highly effective in the prevention and treatment of bacterial diseases. The effectiveness of treatment is achieved through a complex of etiotropic, pathogenetic, and immunostimulating mechanisms of action on animal tissues and physiological systems. The use of probiotics in animal feeding significantly reduces the costs of treating animal diseases while improving animal productivity. Additionally, the use of probiotics worldwide is considered an important component of improving the ecological safety of agricultural products[31].

Probiotic feed additives are capable of increasing the resistance of animal organisms to pathogenic viruses, as demonstrated in the experiment of Hori T. et al. (2002), where laboratory animals were orally administered Lactobacillus casei and Lactobacillus acidophilus, resulting in an increase in

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the number of plasma cells and increased synthesis of antibodies to the influenza virus[32].

However, there are still discussions regarding the dosing of probiotic preparations to achieve positive changes in the overall condition and health of the human and animal body. For example, according to Rijkers, G.T. et al. (2010), the number of live microorganisms in probiotics should be no less than 109 CFU/ml. in order for the number of microorganisms in the gastrointestinal tract to increase 10-100 times after consumption[33].

Consequently, scientific studies aimed at studying the effective dose and the effect of Probion-forte and BioPlus 2B probiotic feed additives on piglets' productive performance and morphofunctional state are relevant and importance.

2. The effect of probiotic feed additives on the morphofunctional state of pigs

Clinical trials of probiotics were carried out in production conditions on piglets of the breed Large-White at 28 days of age. Four experimental groups of 30 piglets each were formed on the principle of analogs. Piglets of group I were fed standard feed with the addition of the probiotic feed additive Probion-forte at a dose of 1g/kg of feed; group II was fed feed with the addition of Probion-forte at a dose of 0.5 g/kg of feed; group III was fed feed with the addition of BioPlus 2B at a dose of 0.4 g/kg of feed for 42 days.

The control group piglets were fed feed according to the norms recommended for the breed Large-White, taking into account the age category. Piglets of group I were fed feed with the addition of the probiotic Probion-forte (produced by Woogene, Korea) at a dose of 1 g/kg of feed, and piglets of group II were fed Bioplus 2B (produced by Biochem, Germany) at a dose of 0.4 g/kg of feed for 42 days. Throughout the study, the general condition of the animals was observed, and on the 14th and 28th day, live weight, feed intake, and retention time of feed in the stomach were determined.

For 42 days of feeding feed with the addition of probiotic feed additives, better assimilation of feed and a gradual increase in the live weight of piglets, in relation to the control group of animals, were noted during the observation period (Fig. 1).

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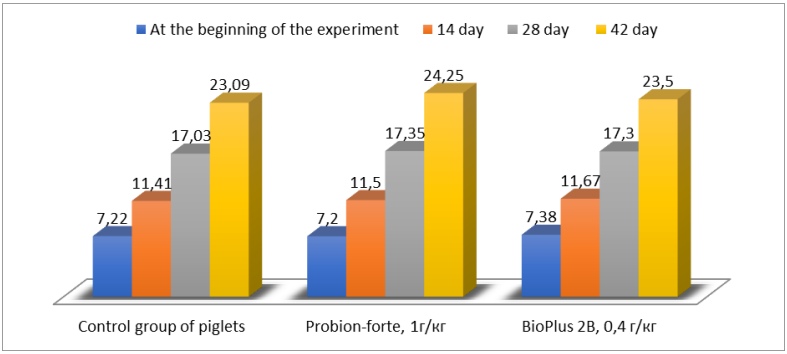

Fig. 1

Dynamics of piglet weight change during feeding with feed supplemented with probiotics (M±m, n=10)

For experimental animals fed full ration for 42 days, the live weight was 23kg. However, for piglets fed probiotics, positive growth dynamics were observed. For piglets fed Probion-forte at a dosage of 1 g/kg of feed, the live weight was 24.2kg, and for piglets fed Bioplus 2B at a dosage of 0.4 g/kg of feed, the live weight was 23.5kg, which was 1.2kg and 0.5kg more, respectively, than the control group.

The most objective indicator of piglet growth intensity is the average daily gains (ADG). As the data (Figure 2) shows, the experimental groups outperformed the control group in terms of average daily gains throughout the entire growing period. A significant difference in indicators was observed on the 42nd day of feeding supplements when the piglets were 70 days old.

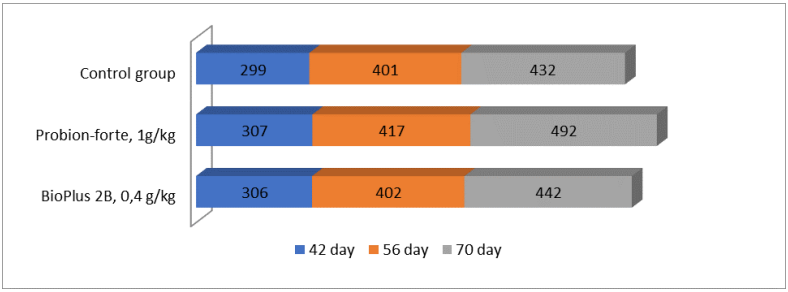

Fig. 2. Dynamics of average daily gains of piglets during feeding of feeds with probiotic additives (M±m, n=10)

Swine fed with the probiotic Probion-forte at a dosage of 1 g/kg, with an average live body weight of 24.25 kg, had a feed conversion ratio of 2.24;

while in animals fed with Bioplus 2B at a dosage of 0.4 g/kg, with an average live body weight of 23.5 kg, the conversion ratio was 2.37. In the control group of animals with an average body weight of 23 kg, the conversion ratio was 2.5 (Table 1).

Table 1

Weight indicators of experimental groups of piglets when fed with feed containing probiotics for 42 days (M±m, n=10)

Index	Probiotics, dose in the feed		
	Control group	Probion-forte 1 g/kg	Bioplus 2B 0,4 g/kg
Body weight of piglets at the beginning of the experiment, kg	7,2±0,12	7,2±0,14	7,3±0,15
Body weight gain during the experimental period, kg	23±0,20	24,25±0,12	23,5±0,17
Feed costs per 1 kg of growth, kg	2,5	2,24	2,37

** – p<0,05; ** – p<0,01; *** – p<0,001.*

Therefore, based on the analysis of productivity indicators in the studied groups of piglets, it can be concluded that the use of the probiotic Probion-forte at a dose of 1.0 g/kg and Bioplus 2B at a dose of 0.4 g/kg in feed contributes to a reduction in feed conversion, an increase in average daily gains, and an increase in live weight of piglets.

In the light-optical study of histological preparations of the duodenum of pigs, it was noted that in the control group of animals, the villi of the mucous membrane were dense, not high, and had a finger-like shape (Fig. 3), and a moderate number of round goblet cells were observed between the prismatic enterocytes. Moderate infiltration of the lamina propria of the mucous membrane with lymphocytes was noted (Fig. 4). In piglets of group I, the villi were leaf-shaped, well-structured (Fig. 5), and somewhat higher relative to the control group of piglets. The prismatic-shaped epithelial cells had a pronounced acidophilic rim on the apical surface (Fig. 6). In piglets of group II, the villi of the mucous membrane were densely arranged next to each other with a moderate number of goblet cells (Fig. 7), while in piglets of group III, the villi were loosely arranged next to each other with a small number of goblet-like cells (Fig. 8).

In the morphometric study, the height of the villi of the mucous membrane of the duodenum of the control group of pigs was 315.13 μm, while in piglets of group I, the height of the villi significantly increased and amounted to 374.64 μm, which 59.51 μm higher than in piglets of the control group (Table 2). Also, in groups II and III, this morphometric indicator was higher by 24.24 μm and 19.74 μm, respectively, compared to the control animals.

The width of the villi of the duodenum of piglets in the control group was 164.96 μm, while in piglets of group I it was 166.32 μm, in group II it was 162.82 μm. However, in piglets of group III, the width of the villi was statistically significantly the smallest and amounted to 145.86 μm. Due to the increase in the height and width of the villi of the mucous membrane, the absorptive surface of the intestine also increases, which improves nutrient absorption and utilization.

The depth of Lieberkuhn's glands of the mucous membrane of the duodenum of piglets of the control group was oval in shape and their depth was 122.71 μm, and in piglets of the I group, the depth of the crypts reliably increased by 18.26 μm and amounted to 140.97 μm. At the same time, a moderate increase was noted of goblet-shaped exocrinocytes in the crypts in comparison with the control group of animals. The width of the crypts slightly increased in the mucosa of the duodenum of piglets of I group and amounted to 46.34 μm, compared to the similar indicator of the control group of 39.87 μm. Also, the width of the crypts in piglets of group III was statistically reliable larger and was 42.83 μm.

Table 2

Morphometric indicators of the duodenum of piglets on the 42nd day of the experiment (M±m, n=5)

Index	Control group	Probion-forte 1 g/kg (I group)	Probion-forte 0,5 g/kg (II group)	Bioplus 2B 0,4 g/kg (III group)
The height of the villi, microns	315,13±1,00	374,64±2,23***	339,37±3,1	334,87±0,76***
The width of the villi, microns	164,96±1,31	166,32±1,08	162,82±2,3	145,86±1,32***
Crypt depth, microns	122,71±1,93	140,97±2,50**	126,45±2,7	123,94±5,34
Crypt width, microns	39,87±0,50	46,34±0,53***	40,71±0,7	42,83±0,51**
Index of villi, units	2,56	2,65***	2,68	2,70***

** – p<0,05; ** – p<0,01; *** – p<0,001.*

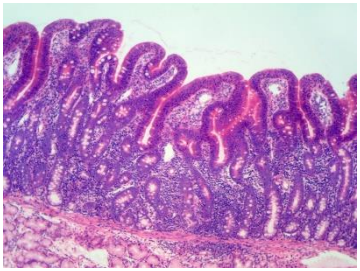

Fig. 3. The mucous membrane of the duodenum in pigs of the control group. H&E stain, x100.

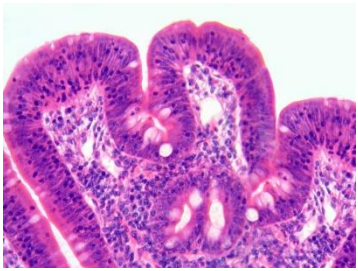

Fig. 4. The structure of the villi of the duodenum in pigs of the control group. H&E stain, x400.

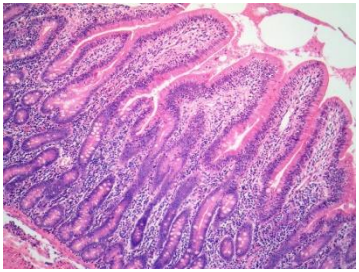

Fig. 5. The mucous membrane of the duodenum in I group. H&E stain, x100.

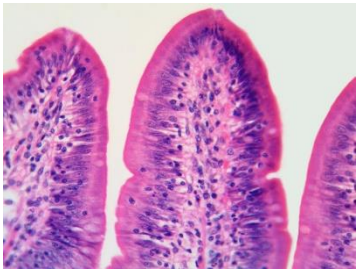

Fig. 6. The structure of the villi of the duodenum in pigs of I group. H&E stain, x400.

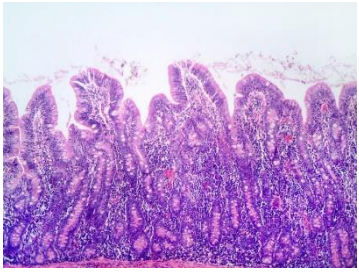

Fig. 7. The mucous membrane of the duodenum in group II. H&E stain, x100.

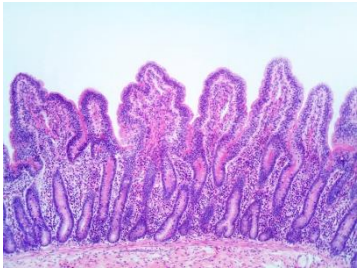

Fig. 8. The mucous membrane of the duodenum in group III. H&E stain, x100.

Fluctuations in morphometric indicators of the morpho-functional structures of the mucous membrane of the duodenum among the experimental groups of pigs led to the formation of different villi indices (the ratio of the

height of the villi to the depth of the crypts). In pigs of the control group, the villi index was 2.56 μm. However, in group I pigs, it was 2.65 μm; in group II, 2.68 μm; and in group III, 2.70 μm, which was significantly higher than its value in the control group of animals.

In the histological examination of DNA and RNA in prism-shaped enterocytes of the mucous membrane of the porcine duodenum in the control group, which were fed full-fledged mixed feeds, moderate pyroninophilia of the cytoplasm of enterocytes (Fig. 9) and pronounced pyroninophilia of the cytoplasm of plasma cells in the lamina propria of the mucous membrane (Fig. 10) were observed. In the mucous membrane of the duodenum of pigs in group I, a more saturated raspberry color of the cytoplasm and nuclei of enterocytes with a blue-green coloration was noted, indicating an increase in the content of RNA and DNA in the cells. Plasma cells were located mainly diffusely in the lamina propria of the mucous membrane and in the region of the crypts and connective tissue of the villi, both in the control group and in the experimental groups of pigs. In the crypts of the lamina propria of the mucous membrane of piglets of the control group, a moderate staining of the cytoplasm of prismatic enterocytes was noted, without brush-border enterocytes and apodocytes.

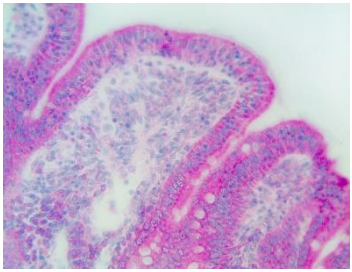

Fig. 9. Villi of the duodenum of pigs from the control group. Pyronine/MG Brachet, x400.

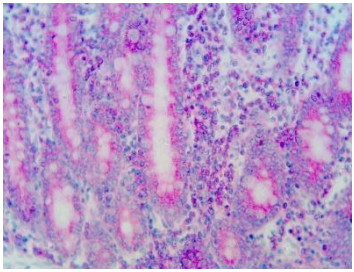

Fig. 10. Plasma cells in the own plate of the mucous membrane of the duodenum of pigs from the control group. Pyronine/MG Brachet, x400.

In pigs of I group, a higher pyroninophilia of the cytoplasm of absorptive enterocytes in the villi (Fig. 11) and without goblet cells in the crypts of the mucous membrane of the duodenum (Fig. 12) was observed compared to the control group of animals.

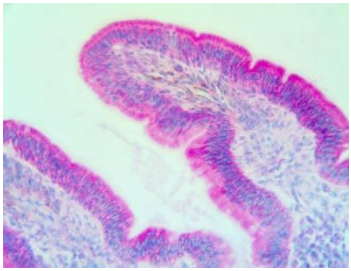

Fig. 11. Villi of the duodenum of pigs from I group. Pyronine/MG Brachet, x400.

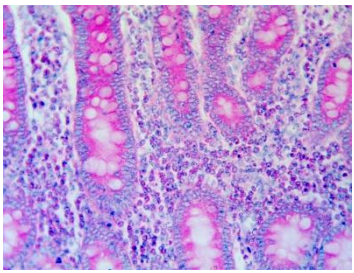

Fig. 12. Plasma cells in the own plate of the mucous membrane of the duodenum. Pigs from the group I. Pyronine/MG Brachet, x400.

Also, an increase in the number of diffusely and associatively located plasma cells with pronounced pyroninophilic cytoplasm and eccentrically located nuclei was noted in the own plate of the mucous membrane of groups II, III (Fig. 13, 14).

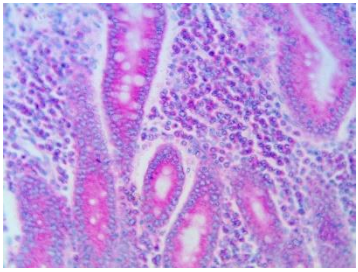

Fig. 13. Plasma cells in the own plate of the mucous membrane of the duodenum. Pigs from the group II. Pyronine/MG Brachet, x400.

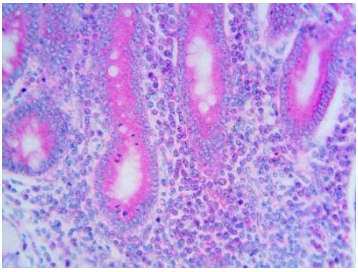

Fig. 14. Plasma cells in the own plate of the mucous membrane of the duodenum. Pigs from the group III. Pyronine/MG Brachet, x400.

At the same time, differences in the ultrastructure of the mucous membrane of the duodenum of pigs were noted. In the control group of pigs, the plasma membrane of columnar cells consisted of two electron-dense layers and a less dense intermediate layer on the apical surface of which microvilli were located, which had different heights and were freely arranged next to each other (Fig. 15).

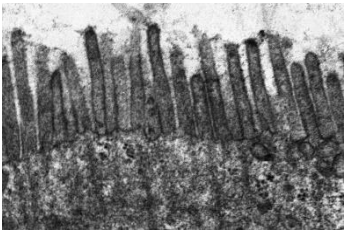

Fig. 15. Microvilli of enterocytes in the mucous membrane of the duodenum. Pigs from the control group. Electron micrograph, x24000.

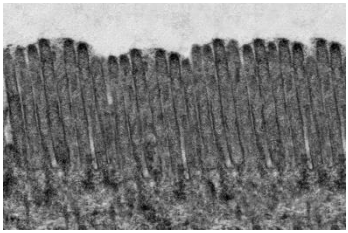

Fig. 16. Microvilli of enterocytes in the mucous membrane of the duodenum. Pigs from I group. Electron micrograph, x24000.

In pigs from I group, the microvilli on the apical surface of the enterocytes were noticeably longer and more densely arranged next to each other, forming a dense brush border (Fig. 16).

The matrix of the microvilli was slightly denser compared to the main substance of the cell cytoplasm. Similar ultrastructure of the microvilli of the mucous membrane was observed in pigs from groups II and III (Fig. 17, 18).

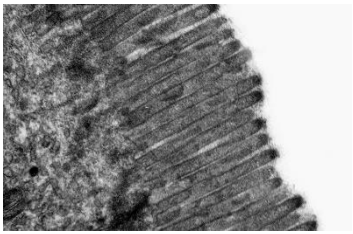

Fig. 17. Microvilli of the enterocyte of the mucous membrane of the duodenum. Pigs of the II group. Electron micrograph, x24000.

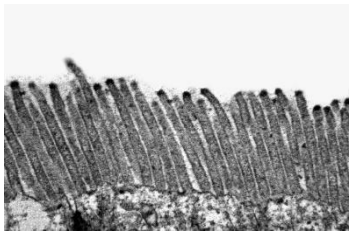

Fig. 18. Microvilli of the enterocyte of the mucous membrane of the duodenum. Pigs of the III group. Electron micrograph, x24000.

It should be noted that there were ultrastructural differences in the nuclei and mitochondria of enterocytes in the experimental groups of animals. In the control group of pigs, the nuclei were mostly irregular in shape with one or several nucleoli, more electron-dense, and with moderate chromatin content. The nuclei of enterocytes from pigs in I group were oval in shape with wavy relief of the karyolemma, slightly widened nuclear pores, and higher content of condensed nuclear chromatin.

Both in the experimental and control groups of pigs, mitochondria in the cytoplasm of enterocytes were more concentrated in the apical region of the cells, mainly oval, rod-shaped, and round in shape and varying in size. In the control group of pigs, the mitochondria of enterocytes had a dumbbell shape and were not very large. In the enterocytes of pigs from the experimental groups, a greater number of mitochondria were observed, which contained a moderate amount of cristae.

CONCLUSIONS

It has been established that feeding piglets with feed containing the probiotic feed additives Probion-forte and BioPlus 2B in different doses contributed to:

– increasing average daily weight gain and live weight gain in piglets when fed with the probiotic Probion-forte at a dose of 1.0 g/kg and Bioplus 2B at a dose of 0.4 g/kg, as well as reducing feed conversion.

– increasing the height of villi and depth of crypts, which promoted the improvement of digestion and absorption processes in the piglets' duodenum.

– increasing the content of RNA and DNA in enterocytes of crypts, which was caused by intensive proliferative processes in the germinal zone of the mucous membrane of the piglets' duodenum, aimed at increasing the villi index.

– the presence of a moderate number of lymphocytes and plasma cells in the mucous membrane plate of the intestinal wall relative to the control group of animals indicates the immunomodulatory properties of the probiotic feed additives, both Probion-forte and BioPlus 2B.

– the dense arrangement of microvilli and changes in the nuclei of enterocytes in the piglets' duodenum indicate an increase in the functional activity of enterocytes and a more pronounced activity of wall digestion in the intestine compared to the control group of animals.

SUMMARY

The purpose of the study was to investigate on average daily gains, morphometric indicators, ultrastructure, and the content of nucleic acids in the wall of the weaned piglets' duodenum when feeding with feed containing different amounts of probiotic feed additives Probion-forte and BioPlus 2B. The study was carried out on 28-day-old piglets of the Large White breed. Four groups of 30 piglets each were formed; the control group was fed a standard feed mix, piglets of group I received a standard feed mix with the addition of probiotic feed additive Probion-forte at a dose of 1 g/kg of feed, group II received a feed mix with the addition of Probion-forte at a dose of 0.5 g/kg of feed, and group III received a feed mix with the addition of BioPlus 2B at a dose of 0.4 g/kg of feed for 42 days. The statistical significance of the differences was determined by Student's t-test, assuming a 5% error rate.

It has been shown that feeding piglets with a probiotic feed supplement called Probion-forte for 42 days at a dose of 1g/kg enhances the height of villi, depth of crypts, and the number of plasma cells in the mucous membrane of the duodenum. This contributes to the digestion process and increases the absorption area of nutrients in the intestine. The increase in the number of plasma cells in the mucous membrane of the duodenum of the piglets in the experimental groups indicates an immunomodulatory effect of the feed supplement. Ultrastructural changes in microvilli and nuclei of enterocytes in the duodenum of the experimental piglets indicate a more pronounced functional activity of enterocytes, which enhances the activity of wall digestion in the intestine.

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