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Structural Changes in the Digestive Tract of Broilers when Introducing a Probiotic

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Abstract

The authors have studied the influence of a probiotic and a gastrointestinal adsorbent on the histostructure of the digestive tract of broilers. Day-old broilers were divided into groups of 50 heads each by the method of analog pairs in terms of live weight. Control broilers received a basic diet. Broilers of the 1st experimental group during the first three days of the experiment received probiotic Vetom-1.1 (0.006%) containing spores of Bacillus subtilis with the basic diet, and broilers of the 2nd experimental group received gastrointestinal adsorbent Enterosgel (0.008%). For histological studies, three heads of broilers were selected at day 1 of age, day 4 of age, and at the end of the experiment (after the end of feeding the preparation and before the transition to the basic diet) from the average weight of each group. Samples were excised from the middle of the crop, the glandular part of the stomach, the duodenum, the jejunum, and the proximal part of the cecum of birds. At the end of the experiment, the positive aftereffect of the preparation persisted in the crop and duodenum. At the same time, in the experimental group, the thickness of the submucous membrane of the stomach decreased, and in the cecum, the layer of villi increased.

Keywords: Probiotic, Broiler, Poultry, Morphology, Intestines, Stomach

Introduction

In the production of poultry meat and eggs, probiotics and sorbents are alternative substances to antibiotics, ensuring not only the health of birds but also obtaining high-quality food for humans. They contribute to maintaining the number of normal intestinal microflora, combating toxins, allergic manifestations, and stabilizing metabolic processes (Kabir, 2009; Habibi *et al.*, 2013; Sukhanova & Makhalov, 2014; Wang *et al.*, 2015; Hmani *et al.*, 2017; Dzhambulatova & Baimukhambetov, 2018; Metwally *et al.*, 2020). An important feature of these substances is the maintenance of the physiological state at the level necessary for the fulfillment of all vital functions of the body. This applies to many systems of the birds' bodies. These include the digestive, circulatory, excretory, and other systems (Samanya & Yamauchi, 2002; Kozhevnikov & Shulgin, 2011; Sukhanova & Makhalov, 2014; Oganov & Kubatbekov, 2015; Alkhudhayri *et al.*, 2018; Dzhambulatova *et al.*, 2018; Kolesnik & Derkho, 2018; Shulgin, 2018). Meat productivity is directly related to the improvement of the microflora of the digestive tract of birds, and it also increases the quality of products (Sukhanova & Makhalov, 2014; Apperson *et al.*, 2017; Markowiak & Śliżewska, 2017; Alkhudhayri *et al.*, 2018; Makhalov, 2018; Novikova *et al.*, 2018). Most of the studies available are related to the influence of probiotic substances on various aspects of the life of farm animals. Much less work of this kind is devoted to the Enterosgel sorbent, which has become widespread, first of all, in the Russian Federation (Kemppinen *et al.*, 2020). Getting into the digestive system along with food, probiotics and sorbents act on the mucous membrane of the tubular organs, with which they are in close contact. The reaction of the mucous membrane leads to a change in the structural and functional state of other membranes of the organ wall, thereby providing its vital functions. This kind of histological work, partially affecting individual parts of the digestive system, was carried out on various species of poultry (Ritz *et al.*, 1995; Samli *et al.*, 2007; Hmani *et al.*, 2017; Fathi *et al.*, 2018; Yakovleva *et al.*, 2018).

The purpose of this study is to determine the effect of Bacillus subtilis and Enterosgel supplements in feed on the histostructure of the wall of various parts of the digestive tract of broilers.

Materials and Methods

The objects of the study were chickens of the Konkurent cross. Chickens were brought at day one of age from the Konkursnyi State Poultry Breeding Center of the Sergiev Posad district of the Moscow region. The experiments were carried out at the zoological station of the Russian State Agrarian University - Moscow Timiryazev Agricultural Academy.

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The control and experimental groups of chickens were formed according to the method of analog pairs according to live weight. The average weight of chickens in groups was 42.0 g. The chicks were kept on the floor, on deep bedding with a stocking density of 15 birds/m^2. The birds had free access to water and feed. The modes of humidity, temperature, and lighting were maintained within the limits recommended by the All-Russian Scientific Research Veterinary Institute of Poultry (VNITIP). The duration of the experiments was 49 days. The design of the first experiment is presented in **Table 1**.

Table 1. Design of the Experiment

Group	n	Days 1-3	Days 4-49
control	50	Basic diet (BD)	BD
1st experimental	50	BD + Vetom 1.1 (0.006%)	BD
2nd experimental	50	BD + Enterosgel (0.008%)	BD

In the first three days, chickens of the 1st experimental group received the BD with the addition of the probiotic Vetom-1.1 (Bacillus subtilis) (6 g per 1 kg of feed), and the second group received Enterosgel (8 g per 1 kg of feed). Subsequently, the chickens of the experimental groups at the age of 4 days were transferred to the BD **(Table 2)**.

Vetom 1.1 is a probiotic preparation containing spores of Bacillus subtilis, soil microorganisms. Entering the intestines, they suppress the development of pathogenic and opportunistic microflora (Alshali, 2019; Amasha & Aly, 2019). The strain used for the preparation of Vetom 1.1 had been modified with a plasmid that synthesized human leukocyte interferon a-2.

Enterosgel belongs to gastrointestinal adsorbents, substances with a cellular structure, due to which they absorb toxins from the gastrointestinal tract of the body and thereby have a positive effect. Enterosgel possesses sorption activity concerning medium-molecular-weight metabolites.

For morphological studies, three heads of chickens were selected from each group (with the average weight), at day 1 of age (before the start of feeding the diet), at day 4 of age (after the completion of the preparation administration and before the transition to BD) and day 49 of age (at the end of the experiment).

Samples (0.5 - 1 cm) from the middle of the crop, glandular stomach, duodenum, jejunum, and cecum were put in 10% neutral formalin. Permanent paraffin histo-preparations were made according to standard methods, the thickness of the layers and shells of the wall of the organs under study was measured. The data obtained was converted into micrometers (the coefficient was calculated using an object micrometer). On their basis, the ratios of the layers and shells of the walls of various parts of the digestive tract were determined. The results were processed statistically.

Results and Discussion

The digestive system of chickens consists of sections, the function of which contributes to the most complete use of rather coarse feed. Starting from the head gut, changes in the membranes and layers of the wall of tubular organs, which are of a morpho-functional nature, are constantly traced. The wall of the esophagus, stomachs, and intestines includes the mucous membrane, the submucous membrane, the muscular and serous membranes. The outermost serous membrane, consisting of connective tissue, is thin and has indistinct boundaries on histological preparations. In this regard, its measurement presents significant difficulties and is not always objective. Therefore, the serous membrane was not measured and was not taken into account in the calculations.

Day-old chicks have the most developed mucous membrane, and the least developed submucous membrane. The thickness of the crop wall increases significantly with the growth of broilers as a whole (by 2.3, 2.8, and 2.4 times in variants C, V, and E, respectively, $P \leq 0.05$). This, to varying degrees, is determined by a change in the absolute values of the membranes of this organ. The mucous, submucous, and muscular membranes grow unevenly and at day 49 of age their sizes increase by 1.6-1.7; 1.5-2.1, and 3.6-5.6 times. The growth rate of all membranes is highest in the first four days of postnatal ontogenesis. 4-day-old broilers can serve as a reference point for establishing the effect of the probiotic and Enterosgel on the histostructure of the crop. During this period, when using Bacillus subtilis, the rapid growth of the muscular membrane is observed, and the mucous membrane and submucous membrane are slightly behind in growth comparing to the birds of the E variant. Similarly, the ratio of the thickness of the membranes forming the wall of the crop changes. Comparable data with experimental poultry were observed in broilers of the control group.

Table 2. The Thickness of the Wall and Membranes of the Crop When Using Probiotic and Gastrointestinal Adsorbent Preparations (n = 20-90)

Group	Membrane thickness			Wall
	mucous	submucous	muscular	
day				
B	358±14.3 61.3	38 ± 5.0 6.5	181 ± 9.7 31.1	583 ± 24.0
4 days				
C	600 ±18.9 45.7	79 ± 8.3 6.0	634 ± 26.3 49.3	1313 ± 46.3
V	623 ±17.6 38.0	85 ± 5.6 5.2	933±34.9* 56.8	1641±38.2*

E	761 ± 27.1* 51.8	119 ± 26.6 8.1	588 ± 38.5 40.1	1468 ± 55.6
		49 days		
C	598±17.6 45.2	57 ± 3.8 4.3	668 ± 33.3 50.5	1322 ± 44.5
V	567±14.2 34.3	78 ± 5.0* 4.7	1011±29.01* 61.0	1656 ± 34.5*
E	619 ± 41.9 45.1	75 ± 11.8 5.5	679 ± 45.3 49.4	1373 ± 71.5

Here and in **Tables 3-6**: B means the beginning of the experiments (day-old chickens), C means the control group (BD), V means the 1st experimental group (Vitom 1.1), E means the 2nd experimental group (Enterosgel). The difference in comparison with the control group is significant at P≤0.05. Above the line, we can see the absolute values, and below the line the relative values of the membrane thickness.

In contrast to the crop, in day-old chickens, the wall of the glandular stomach is thicker (3.1 times, P≤0.05). This is due to well-developed mucous and submucous membranes. Smooth muscle cells adjoin the submucous membrane in the form of a relatively narrow strip. (107 microns), the share of which is 5.9%. At the same time, similar to the crop, in the first four days, the thickness of the wall of the glandular stomach increases significantly. However, in the process of growth, the relative size of the mucous membrane decreases, but this is not associated with the addition of Vetom and Enterosgel to the feed. The proportion of the submucous membrane increases significantly in chickens of all studied groups. However, by the end of the experiment, the addition of the probiotic and Enterosgel to feed leads to some suppression of the submucous membrane (control group: 77.8%; experimental groups: 73.9-74.6%). The muscular component of the glandular stomach in all 49-day-old broilers is relatively poorly developed in comparison with other membranes and does not go beyond 10%.

Table 3. The Thickness of the Wall and Membranes of the Glandular Stomach When Using Probiotic and Gastrointestinal Adsorbent Preparations (n = 25-100)

Group	**Membrane thickness**			**Wall**
	mucous	**submucous**	**muscular**	
		day		
B	539±19.8 29.7	1168 ±37.1 64.4	107 ± 3.7 5.9	1813 ±44.9
		4 days		
C	461 ± 12.5 17.8	1860 ±49.6 71.7	272 ± 8.5 10.5	2592 ± 48.3
V	371±2.4* 15.7	1746±52.16 74.0	242±8.7 10.3	2358±55.7*
E	457 ±17.7 14.7	2410±84.1* 77.7	236 ±19.1 7.6	3103±79.5*
		49 days		
C	619 ± 14.9 14.6	3269 ± 47.6 77.8	367 ±10.7 8.6	4255 ± 52.4
V	717±18.4* 16.0	3350±51.7 74.6	424±9.5* 9.4	4490± 52.6*
E	682 ± 19.9* 17.4	2896±97.3* 73.9	340±12.5 8.7	3918±103.9

In the duodenum of day-old broilers, the mucous membrane occupies 86.4% of the wall thickness. The submucous membrane is poorly developed (2.2%). The muscle component is thicker than in the glandular stomach. In the mucous membrane, villi occupy 90%, crypts are 10 times smaller. When fattening, the absolute thickness of the mucous membrane and its components increases, which affects the relative indicators to a lesser extent. The influence of Vetom and Enterosgel on the ratio of the height of villi and crypts is insignificant. The submucous membrane and muscular membranes respond to probiotic and sorbent supplements by increasing in size more actively (the submucous membrane increases by 22.5-34.5%; and the muscular membrane by 25.1-28.3%; P≤0.05).

Table 4. The Thickness of Duodenal Membranes When Using Probiotic and Gastrointestinal Adsorbent Preparations (n = 150)

Group	**Membranes**					**Wall**
	mucous			**submucous**	**muscular**	
	villi	**crypts**	**whole**			

			day			
B	568±8.3 90.2	61±1.4 9.8	629±8.1 86.3	15 ± 0.5 2.2	84±1.8 11.5	729±7.9
			4 days			
C	855±10.0 89.0	105±2.4 11.0	960 ± 10.2 89.8	17 ± 0.5 1.6	92 ± 2.1 8.6	1070±9.9
V	841±7.8 89.8	96±1.9* 10.2	937±8.4 89.5	17 ± 0.5 1.6	93 ± 3.2 8.9	1046±8.5
E	953±6.3* 90.2	103±2.1* 9.8	1056±6.6* 89.9	16 ± 0.4 1.4	102±2.2* 8.7	1174±7.4*
			49 days			
C	1388 ±17.9 89.1	169±3.5 10.9	1558 ± 18.4 86.3	29 ± 0.6 1.6	219.1 ±5.44 12.1	1806±18.5
V	1573±24.1* 89.7	181±3.1 10.3	1753±24.2* 84.9	37±0.7* 1.8	274±5.5* 13.3	2065±23.7*
E	1563±18.2* 88.8	197±5.9* 11.2	1760 ±20.2* 84.6	39 ± 0.9* 1.9	281 ± 5.8* 13.5	2080±18.0*

In the jejunum, similar changes were noted as in the previous section of the small intestine. At the same time, in the control and variant E, the absolute values of the thickness of the mucous membrane and the layer of villi were lower than when using Vetom (P≤0.05), which did not affect the relative indicators.

Table 5. The Thickness of the Wall and Membranes of the Jejunum When Using Probiotic and Gastrointestinal Adsorbent Preparations (n = 60-120)

Group	Membranes					Wall
	mucous			submucous	muscular	
	villi	crypts	whole			
			Day 1			
B	313 ± 6.4 88.3	41±1.2 11.7	355 ± 6.7 81.5	14 ±0.5 3.1	67 ± 2.1 15.4	436±8.0
			4 days			
C	549 ± 11.0 83.9	105±3.8 16.1	654±13.4 86.2	18 ±0.8 2.4	87 ± 3.2 11.4	759±15.8
V	565 ± 9.4 85.0	99 ± 3.9 15.0	664±11.8 86.1	16 ±0.8 2.12	91 ± 3.1 11.8	772±14.2
E	471±9.0* 85.9	78 ± 2.3 14.1	549 ± 8.2* 78.6	22 ±0.9* 3.1	128±5.3* 18.3	699±7.83*
			49 days			
C	1532 ±25.1 92.3	128 ± 2.9 7.7	1660±25.8 89.9	31 ±0.7 1.7	156 ± 4.7 8.4	1847±27.2
V	1713±32* 92.9	132 ± 8.9 7.1	1845±34.7* 88.5	36,±0.9* 1.7	205±4.5* 9.8	2086±37.8*
E	1472 ±53.5 91.7	133 ± 5.8 8.3	1604±55.7 89.0	31 ±1.6 1.7	168 ± 5.2 9.3	1803±58.2

The crypts are better developed in the proximal cecum than in the small intestine. The muscular layer is thicker, but the wall is generally thinner than in other parts of the intestine. In the initial period of broiler growing, the probiotic and sorbent have a depressing effect on the structures of the villi, and then, on the contrary, these substances stimulate their development (P≤0.05). Both supplements have the same effect on the mucous membrane, increasing its size, which also affects the width of the wall. In broilers, the value of this indicator when using Vetom and Enterosgel is higher than in the control group by 18.4 and 13.0%, respectively.

Table 6. The Thickness of the Wall and Membranes of the Proximal Part of the Cecum When Using Probiotic and Gastrointestinal Adsorbent Preparations (n = 120-130)

Group	**Membrane thickness**					**Wall**
	mucous			**submucous**	**muscular**	
	villi	**crypts**	**whole**			

day						
B	282 ±7.0 81.5	64 ±1.81 18.5	347 ±6.8 75.6	16±0.8 3.7	95 ± 2.9 20.7	459 ± 7.7
4 days						
C	433 ±6.2 86.2	69 ± 2.0 13.8	503 ± 7.1 80.0	17 ±0.7 2.8	108 ± 3.0 17.2	628 ± 7.1
V	408±6.4* 85.9	67 ± 1.8 14.1	475 ±6.4* 80.5	18 ±0.9 3.1	98±2.4 16.6	590±6.2*
E	411 ± 4.5* 86.2	67 ± 1.8 13.8	477 ± 4.9* 80.0	16 ± 0.6 2.7	103 ± 3.2 17.3	596 ± 5.9*
49 days						
C	790 ± 11.7 90.2	87 ± 2.5 9.8	876 ± 11.9 77.0	23 ± 0.8 2.0	237 ± 5.6 20.8	1137 ± 14.6
V	955±16.3* 92.0	83 ± 2.2* 8.0	1038 ± 15.6* 77.1	23 ± 0.8 1.7	284 ±7.3* 21.1	1346±16.7*
E	947±11.8* 92.6	76± 2.3* 7.4	1023 ± 11.7* 79.6	25 ± 0.70 1.9	237 ± 3.5 18.4	1285±12.6*

The foregut in birds consists of organs that stand first in the path of food. These organs are responsible for the preparation and the initial stages of food processing. The crop is necessary for the accumulation, wetting, maceration of the feed and its advance into the lower parts of the digestive tract. In this case, the structures that make up the crop and the glandular stomach react differently, first of all, to the composition of the BD. In early postnatal ontogenesis (in this case, this is the first four days), an increase in the thickness of all membranes and the wall of the crop as a whole is observed. This is due to the proliferation of stratified epithelium and the lamina propria with tubular glands located in it. The most significant size of the mucous and submucous membranes in birds during this period was noted in the group with the use of gastrointestinal adsorbent. During the fattening period, the thickness of the crop wall changes little, and even slightly decreases in the mucous and submucous membranes, which, corresponds to the normal state. The development of the muscular membrane remains at the same level, ensuring effective evacuation of feed.

Since the glandular stomach is located farther from the head gut and the food entering it is already prepared for digestion, its effect on the wall membranes has a different character. In the first four days, the thickness of the broiler mucous membrane, regardless of the variant, decreases by 15-30%, but most significantly when Bacillus subtilis is added to the feed. A different picture is observed when considering the submucous membrane, where deep complex alveolar glands are located, producing digestive juice. For the first four days, the submucous membrane increases by 1.5-2.1 times. This is due to hypertrophy of the submucous membrane and its glands reacting to the incoming food into the stomach. The highest value of this indicator was noted when Vetom was added to the feed. Subsequently, with the adaptation of the body of birds to feed, certain changes are observed in the digestive system. The proportion of mucous and muscular membranes in the stomach increases, and in some cases a reliable connection can be established with the use of Vetom (probiotic) and gastrointestinal adsorbent. Together with this, the relative width of the submucous membrane also changes.

In the duodenum, where various substances are digested, the mucosa is well developed, primarily due to the villi, the height of which increases throughout the experiment. These structures reach their maximum values in birds that received probiotic and Enterosgel supplements with feed. This increases the absorption surface of the epithelium and parietal digestion. The presence of a large number of goblet cells secreting mucus ensures better movement of the contents through the intestine. In addition, in the process of growth, the value of the crypt layer also increases, providing renewal of the epithelium. These layers are better developed in experimental broilers. All these are consistent with the activation of digestive processes in the duodenum of the birds receiving Vetom and Enterosgel. The stimulating effect of these substances on the duodenal wall is confirmed by the development of the submucous membrane and muscular membranes, with relatively close relative values.

The structural changes that occur in the jejunum are virtually the same as in the duodenum. This part of the intestine is located at a greater distance from the oral cavity, and therefore the effect of Enterosgel seems to weaken, while the activity of Bacillus subtilis remains at a rather high level. In this regard, microorganisms of direct action (Vetom) contribute to the better development of the layer of villi and crypts and the mucous membrane in general. The size of the absorption surface and the enhancement of metabolic processes in the epithelial cells of various parts of the small intestine are supposedly associated with the height of the villi and crypts (Awad *et al.*, 2006; Alagawany *et al.*, 2018; Yakovleva *et al.*, 2018). It should be borne in mind that microorganisms of direct action (PrimaLac and Salinoycin) have an ambiguous effect on different parts of the small intestine. In the duodenum, under the influence of these substances, the height of the villi and crypts increases, and in the ileum, on the contrary, it decreases (Skřivanová *et al.*, 2017).

A decrease in the length of the villi and the depth of crypts leads to a decrease in the absorption of nutrients, an increase in the processes of secretion, thereby lowering the functional activity of the digestive tract (Upadhaya *et al.*, 2019). At the same time, the size of the villi is directly related to the activity of mitosis in epithelial cells (Samli *et al.*, 2007). In addition to Vetom and

Enterosgel, villus elongation is promoted by Lactobacillus reuteri and arnylase (Chichlowski *et al.*, 2007; Zhang *et al.*, 2021).

The cecum has a closed head and the movement of the chyme in this part is less active than in other parts of the intestine. The main function of this intestine is to absorb water and salts. The intensity of absorption depends on the development of mucous membranes, villi, and crypts. The cecum is characterized by a large number of bacterial colonies. Bacteria and substances that enter the body orally can, after passing through virtually the entire digestive system, linger for some time and concentrate in the proximal part of the cecum. This apparently can be explained by the fact that the transport of substances in the cecum begins immediately after hatching, but with the development of the chicks, it becomes more passive (Xu *et al.*, 2003). Therefore, Vetom and Enterosgel can influence the mucous membrane, stimulating its development. This leads to an increase in the size of both villi and crypts.

Judging by the available data, due to the introduction of probiotics, growth, live weight gain, the safety of birds, increase, and feed costs are reduced (Kalia *et al.*, 2007; Samli *et al.*, 2007; Berkold, 2009; Kozhevnikov & Shulgin, 2011; Hussar *et al.*, 2017; Yakovleva *et al.*, 2018). Enterosgel, in addition to affecting the histological structure of the wall of tubular organs, has a therapeutic effect, ensuring the safety of young birds (Howell *et al.*, 2019; Crini *et al.*, 2019; Kemppinen *et al.*, 2020). The reaction of somatic structures and internal organs to probiotics is ambiguous (Fathi *et al.*, 2018; Yakovleva *et al.*, 2018; Soomro *et al.*, 2019). The carcass and other parts of the body do not change in comparison with the control group when various probiotics based on Bacillus subtilus, Bacillus licheniformis, Lactobacillus cerevisiae, etc. are added. The exception is the hind limbs, which are better developed in experimental broilers (34.0% versus 32.2% in the control group) (Novikova *et al.*, 2018). The synbiotic (Biomin IMBO) allows obtaining broilers with a higher relative carcass weight compared to the probiotic (Lactobacillus sp.). However, visceral organs such as the liver, spleen, and some others have a higher relative mass. Various supplements do not affect the tubular digestive organs: the cecum and colon (Yakovleva *et al.*, 2018).

Structural changes in the digestive system of birds are due to both the location of its divisions and morphological and functional features. Both substances used in our work (Vetom and Enterosgel) have a specific effect on the walls of the tubular organs. Changes, sometimes significant, begin on the first day of development of the chickens as food advances in the crop. Subsequently, they are leveled, to one degree or another, which is associated with the importance of a particular department in the digestive process. The mucous membrane, which can be traced not only in the small (duodenum and jejunum) section but also in the large (proximal part of the cecum) section of the intestine is influenced by probiotic and gastrointestinal adsorbent preparations more than other parts of the tract. No cardinal differences in the histological structure of the tube-like organs of broilers were found when using Vetom 1.1 and Enterosgel. Functionally, they can be comparable and, if necessary, implemented for using in broiler farming.

Conclusion

Structural changes in the digestive system of birds are due to both the location of its divisions and morphological and functional features. Both substances used in our work (Vetom-1.1 and Enterosgel) have a specific effect on the walls of the tubular organs. Changes, sometimes significant, begin on the first day of development of the chickens as the food progresses in the digestive tract, starting with the crop. The mucous membrane, which can be traced not only in the small (duodenum and jejunum) section but also in the large (proximal part of the cecum) section of the intestine is influenced by probiotic and gastrointestinal adsorbent preparations more than other parts of the tract. Differences in the action of the probiotic and gastrointestinal adsorbent preparations have been established. Probiotic Vetom-1.1 initially has a suppressive effect on the mucous membrane, while Enterosgel, on the contrary, enhances its development. Both preparations are characterized by a positive aftereffect on the structures of the gastrointestinal tract. For Vetom this is typical throughout the entire length of the digestive tube, and for Enterosgel only in the initial sections (glandular stomach and duodenum). Probably, Bacillus subtilis, bypassing the gastrointestinal tract, contributes to the formation of a favorable flora along its entire length, which determines the effect at the end of the experiment. The influence of Enterosgel is due to its adsorption capacity. The dosage we used allowed the preparation to affect the initial sections of the gastrointestinal tract.

As a result of the experiment, no cardinal differences were found when using Vetom-1.1 and Enterosgel on the histostructure of the tubular digestive organs. Functionally, the preparations can be comparable. By stimulating the development of the mucous membrane, they contribute to better absorption of nutrients and create conditions for broilers to gain live weight. This makes the investigated preparations promising for use in broiler farming.

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