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Morphometric features of the duodenal wall in piglets during different periods of postnatal and neonatal ontogenesis under the influence of the 'Globigen Jump Start' feed additive

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The morphological parameters of the small intestinal mucosa, such as villi size and crypts, play a key role in the formation of the intestinal tube's absorption surface. The number of goblet and enterochromaffin cells indicates the epithelium's functional condition in terms of mucus secretion and production of catecholamines and hormones (serotonin, dopamine). That is why it is important to study and determine certain morphometric parameters of the duodenal wall in piglets during different periods of neonatal and postnatal development, especially during stress situations, namely weaning and transition to protein feeding. The article presents the resulting effect studies of 'Globigen Jump Start' feed additive on the histo-morphological parameters of the piglets' duodenal mucosa on day 7, 14 and 28 of life. A positive effect on mitigating weaning stress was manifested by a decrease in the quantitative and linear indicators of histoarchitectonics of intestinal wall's individual morphological components. A significant increase in goblet cells, especially in the experimental group, had a positive impact on the mucopolysaccharide synthesis. The piglets' gastrointestinal tract physiology involves a complex interaction between the central nervous system, metasympathetic nervous system, APUD system, and endocrine system. Due to these systems, the information is transmitted according to the direct and reverse communication mechanisms in the regulation of the gastrointestinal tract function. An increase in the number of enterochromaffin cells and their nuclei diameter in the experimental group of piglets indicated an increased synthesis of catecholamines and hormones. It has an extremely positive effect on the immune and physiological status of piglets, thus emphasizing the crucial role of serotonin in neuronal metabolism and the formation of stress resistance. The increase in the thickness of the duodenal wall muscle layer, in our opinion, occured due to the active peristalsis, which was enhanced by the action of some catecholamines, which were synthesized in a slightly larger amount under the influence of nutrients making up the 'Globigen Jump Start' feed additive.

Key words: piglets, duodenum, villi, crypts, goblet cells, enterochromaffin cells, yeast, egg powder

Introduction

The development of the gastrointestinal tract (GIT) in pigs is a complex physiological process that begins in a prenatal period with the subsequent genesis in a postnatal one. It is known that colostrum and sow's milk contain biologically active substances that exert a positive impact on the GIT development, allowing it to adapt to feeding changes. At the same time, due to insufficient secretion of digestive enzymes in early weaned piglets, the roughage cannot be digested quickly in the gastrointestinal tract, which partially leads to the intestinal barrier destruction [11]. As reported by Pluske in his research [22], such physiological changes affect the small intestine's absorption capacity, growth, and development of piglets. Hampson [10] found the villi height in the small intestine decreased by about 25–35% during the first 24 hours after the weaning and remained at this level for up to five days. In non-weaned piglets, on the contrary, the correlation in the villi height was insignificant [37]. The same researchers also noted the elongation of crypts in the weaned piglets, which was recorded during the first 11 days after the feeding change [36].

A decrease in the digestive enzymes' activity on the brush border of enterocytes is also known to decrease in the gastrointestinal tract of the piglets after weaning [11]. Lalles et al. [17] reported a decrease in lactase and aminopeptidase activity within 15 days after weaning, while maltase activity decreased within 2 days with a subsequent increase by the 15th day after weaning. In addition, a number of authors found a short-term decrease in pancreatic secretion up to 15 days after weaning. These and some other changes can affect the small intestine's functional activity, its secretory and barrier functions, and the feed digestion intensity [29, 30, 31].

Modern pig breeding technologies and multifertility of sows provide for early weaning of piglets, mainly at the age of 21 to 28 days. The strategy of gradually transitioning piglets from milk to roughage has been used to reduce the stress of weaning. Accordingly, the piglets are accustomed to consuming various feed additives from the first week of life [18]. For instance, when using yeast as a feed additive, the productivity and growth stimulation improved due to the presence of relatively high levels of protein, vitamins, biologically active substances, amino acids, energy, and trace elements in yeast.

Chowdhury and Knabe [5] investigated the effect of *S. cerevisiae* yeast and aspartic acid on breeding boars and revealed an increase in their productivity. White et al. [35] demonstrated an increase in lactobacilli number and a decrease in bifidobacteria number in the intestine of weaned piglets when feeding yeast, while Stanley et al. [27] recorded a decrease in the population of coliforms. Sauerwein et al. explained in their work [25] that the preservation of normal intestinal morphology occurred due to the binding and reduction of pathogen colonization in the gastrointestinal tract, which helped improve the intestinal mucosa integrity and enhanced the immune system activity.

To reduce feeding-related stress and improve piglet health, egg powder obtained from hens sensitized to certain pathogens is added to feed additives, serving as a source of specific immunoglobulins, vitamins, omega-3 fatty acids, antioxidants, and trace elements. One of the main proteins contained in egg powder is ovomucin and the enzyme lysozyme [1]. In addition, egg powder contains such amino acids as tryptophan, alanine, valine, lysine, and methionine. The synergistic effect of these bioactive nutrients helps improve the piglets' growth, immunity, and health.

Many studies prove that lysozyme enhances the intestinal function and protects it from enteropathogenic strains of *Escherichia coli* in newborn piglets [15]. Ovomucin and its derivatives have anti-inflammatory, antioxidant, and immunomodulatory properties [1, 33, 39].

It is known that the physiology of piglets' GIT involves a complex interaction between the central nervous system, the metasympathetic nervous system, the APUD system, and the endocrine system, through which information is transmitted by direct and reverse communication mechanisms regulating the tract's function. Enterochromaffin cells (ECs) of the gastrointestinal tract play an important role in this complex process, performing the function of forming catecholamines, hormones, and affecting intestinal motility and secretion [9, 24]. Research by some scientists has shown that enterochromaffin cells express sensory receptors, the activation of which promotes the release of 5-HT serotonin receptors with subsequent stimulation of intestinal contractility [7].

Anatomically, the small intestine of pigs is divided into three parts: the duodenum (accounting for approximately 4–4.5% of the total small intestine volume in adult pigs), the jejunum (approximately 88–91%) and the ileum (about 4–5%) [8]. Histologically, the intestinal mucosa is divided into four main membranes: mucosal, submucosal, muscular, and serous. The mucosa consists of the epithelial layer, a mucosal lamina propria, and a muscular lamina propria. The intestinal epithelium is characterized by a folded surface, which is manifested at different levels of organization by intestinal folds, forming finger-like protrusions called villi with their own vascular, muscular, and nervous apparatus. At the base of the villi, the epithelial layer forms protrusions known as Lieberkuhn crypts (intestinal glands). The microvilli increasing the absorption surface are located on the luminal surface of enterocytes. It should be noted that the morphology of the gastrointestinal villi differs throughout the intestinal tract of animals, depending on the intestines function. The villi length increases from the duodenum to the middle of the jejunum and decreases towards the distal ileum. Similarly, the crypts also vary in size and composition along the intestine: they are deeper in the duodenum and jejunum and less deep in the ileum [6]. On the villi surface, three types of cells are localized, which derive from stem cells located at the crypt base: enterocytes (94%), goblet cells (up to 5%), and enteroendocrine cells (about 1%) [20, 21]. Small intestine enterocytes are divided into absorptive cells, goblet cells,

Pannet cells, and undifferentiated enterocytes. The enzymatic activity of enterocytes begins when they reach the basal third of the villus axis, while the absorptive function begins when they reach the apex and the upper third of the villus. Goblet cells are secretory which means they secrete viscous mucus; their basal activity increases when the cells come into contact with substances that cause secretion. The third type of cells, namely enteroendocrine cells, produce catecholamines, hormones that play an important role in the gastrointestinal tract functioning [9].

Physiological changes in the mucosa associated with absorption and barrier function are usually expressed by its morphological parameters. Thus, qualitative functional and morphological parameters of the small intestinal mucosa, such as the size of villi and crypts, and the activity of brush border enzymes, can provide additional information about the functional condition of the animal organism [23]. Other functional and morphological parameters, such as the number of goblet and enterochromaffin cells, are the parameters indicating the epithelium condition and the mucous membrane function as a barrier between the intestinal lumen and body tissues.

The **aim of our work** was to define individual morphometric parameters of the piglets' duodenum during different periods of neonatal and postnatal ontogenesis and determine the number of goblet and enterochromaffin cells under the influence of the 'Globigen Jump Start' feed additive.

Materials and Methods

The study of the 'Globigen Jump Start' feed additive effectiveness among the weaned piglets was carried out at the *Barkom* farm in the Lviv region. For this purpose, two groups of ten piglets each of the Large White breed were formed, which were fed with the feed additive from 7 to 28 days of life. During the experiment, piglets of the control group received a standard nutrient-balanced diet, and piglets of the second experimental group were fed 2 kg of the 'Globigen Jump Start' additive per 1 t of feed. The additive contains dry yeast and egg powder enriched with immunoglobulins (manufactured by *EW Nutrition* GmbH, Germany). The main feed was given in the form of pellets, which met the needs of piglets in all nutrients. During the experiment, the piglets were kept in the same conditions with free access to feed and water. Weaning was performed at 28 days of age. On days 14 and 28, three animals from each group were euthanized and material was taken for histological examination.

To study the cyto- and histoarchitectonics of the duodenum, its fragments were fixed in a 10% neutral aqueous solution of formalin and Bouin's fluid, dehydrated through the ascending series of alcohols, and embedded in paraffin blocks after I and II chloroforms. Sections of 7 μm thickness were made from the obtained blocks on a microtome MS-2, which were mounted on a glass slide, and stained with hematoxylin and eosin after drying [19].

To detect enterochromaffin cells, the diazo reaction was used as a staining method. Sections were deparaffinized and saturated with water. For 30 seconds, the sections were treated with a dilute solution (1 mg/ml) of stabilized 5-nitroanisidine diazotate (Fast Red salt B) in 0.1 M veronal acetate buffer (pH 9.2). They were thoroughly washed in running water. The nuclei were stained with Mayer's hematoxylin for 6 min followed by rinsing in running water for 30 min. After that, the sections were dehydrated in alcohols, enlightened in xylene, and embedded in balsam. On histological preparations, the granules of argentaffin cells were stained orange-red, nuclei — dark blue, and cytoplasmic structures — yellow [19].

The McManus PAS reaction was used to detect goblet cells. Sections were deparaffinized, saturated with water, and oxidized with 0.5% aqueous iodic acid solution for 2 min followed by rinsing in distilled water. They were treated with Schiff's reagent for 10 min and rinsed in running water for 10 min. The nuclei were counterstained with Mayer's hematoxylin for 3 min and rinsed thoroughly with running water. The sections were dehydrated in alcohols, enlightened in xylene, and embedded in balsam. The mucoproteins and neutral mucopolysaccharides were intensively stained in purple-red color.

Using the *Aperio Image Scope* software, the villi height, crypt depth, circular and longitudinal muscle layer thickness, and the number of goblet and enterochromaffin cells per 0.45 mm^2 in 5 fields of view were determined on histological specimens. Statistical processing of the results was performed using a one-factor ANOVA analysis of variance with Bonferroni correction. For this purpose, the StatPlus program (*Analyst Soft* Inc., USA) was used. The results are presented as Mean±SD. Differences between groups of animals were considered statistically significant at $P<0.05$, $P<0.01$, $P<0.001$. Finished histological preparations were photographed using a *Leica DM-2500* microscope (Switzerland) with a *Leica DFC450C* camera and *Leica Application Suite Version 4.4* software. During the research, the requirements of ethical treatment with animals used in experimental studies were fully observed (Strasburg, 1986; Kyiv, 2002), and the research methodology itself was approved by the bioethical commission in the Institute of Animal Biology (National Academy of Sciences of Ukraine; Protocol no. 93-01 dated June 3, 2021).

Results and Discussion

Investigating the histo-morphometric parameters of the duodenum in the piglets' on day 7 of life, which consumed exclusively milk from the sow, it was found that the villi height was quite high and amounted to 696.35 μm, the crypt depth was 240.72 μm, consequently, the ratio of the villi height to the crypt depth was 2.89. It should be noted the thickness of the muscle membrane's outer longitudinal layer was 180.25 μm, and that of the inner circular layer — 146.96 μm.

Studying the morphological structure of the piglets' duodenum wall during the changes in feeding, we noted some differences in its morphometric parameters when introducing roughage into the diet and using the 'Globigen Jump Start' feed additive. Thus, in piglets of the control group, which consumed a standard nutrient-balanced diet from the 7th day of life, a decrease in the villi height by 29.53% was noted compared to 7 days before feeding. Whereas in piglets of the experimental group, which were fed with the 'Globigen Jump Start' additive, an insignificant decrease in the villi height was observed, compared to the same indicator on the 7th day (by 22.04 μm) and a significant increase in comparison with the control group on the 14th day by 37.42% respectively (table 1).

A similar trend was observed with the crypt depth parameters. In piglets on day 14 of the experiment in the control group, the crypt depth was 314.13 μm, while in the experimental group it was 413.02 μm, which is 31.48% higher than in the control one. On the 28th day of the experiment, piglets of both groups showed slight differences in the villi height: 654.51 μm in the control group and 675.32 μm in the experimental one. The crypt depth in the control group was significantly higher (P<0.01) compared to that on day 14 and equaled to 528.96 μm. In the experimental group, the crypt depth was 423.03 μm, i.e. literally unchanged. The total thickness of the duodenal wall muscle layers during the experiment also correlated a bit, which probably happened due to the beginning of roughage consumption. On day 7 of life, before feeding additive, the muscle wall was 327.21 μm, on day 14 — 327.93 μm in the control group and 404.44 μm in the second experimental group; on day 28 — 426.76 μm and 405.25 μm in the control group and experimental one respectively (table 1).

Some correlation was also found when counting the number of goblet and enterochromaffin cells of the duodenal mucosa on the area of 0.45 mm^2 (fig. 1). According to table 2, the number of goblet cells in piglets on day 7 of life amounted to 80 cells. A slightly lower number of them was found on day 14 with the introduction of dry feed and the 'Globigen Jump Start' additive, namely 67.8 and 71.0 cells respectively. At the same time, on day 28 of the experiment, a significant increase in the number of goblet cells was observed, compared to day 14 in both the control and experimental groups (P<0.05). In the control group, the number of goblet cells was 94.6, and in the experimental one — 96.3 cells.

Analyzing the number of enterochromaffin cells, it was noted that 7-day-old piglets had the lowest number of them, namely 7.8 cells. On day 14, in both groups, their increase was noted, by 2.56% and 7.69% respectively, compared to day 7 (fig. 2). A significant increase in the number of these cells was noted on day 28 of the experiment. Actually, the number of enterochromaffin cells was 9.8 in the control group and 12.4 in the experimental one (P<0.05).

Table 1. Morphometric parameters of the piglets' duodenal wall in the control and experimental groups fed with the 'Globigen Jump Start' additive (n=5, M±SD)

Morphological structures	7th day	14th day		28th day	
	Before feeding	Control group	Experimental group	Control group	Experimental group
Villi height, μm	696,35±43,94	490,67±30,22**	674,31±25,05	654,51±14,81***	675,32±12,44
Crypt depth, μm	240,72±11,49	314,13±21,54**	413,02±10,03***	528,96±20,12***	423,03±18,35
Villi height to crypt depth ratio (V:C)	2,89	1,56	1,63	1,24	1,59
Thickness of the muscle membrane's outer longitudinal layer	146,96±1,97	143,27±2,09	194,02±6,97***	166,31±3,90***	160,08±3,07
Thickness of the muscle membrane's inner circular layer	180,25±2,45	184,66±3,34	210,42±4,94***	260,45±12,76***	245,17±10,54
Muscle membrane thickness	327,21±2,12	327,93±2,07	404,44±4,23	426,76±7,24	405,25±5,23

Note. Here and further: * — P<0.05, ** — P<0.01, *** — P<0.001 compared to the previous day of the experiment.

Table 2. The average number of enterochromaffin and goblet cells in the duodenal mucosa of piglets fed with the 'Globigen Jump Start' additive (n=5, M±SD)

Parameters	7th day	14th day		28th day	
	Before feeding	Control group	Experimental group	Control group	Experimental group
Number of goblet cells	80,0±7,47	67,8±5,38	71,0±4,73	94,6±8,35*	96,3±5,36*
Number of enterochromaffin cells	7,8±0,86	8,0±0,70	8,4±1,02	9,8±0,73	12,4±1,69*
Enterochromaffin cells' nucleus volume	108,19±5,80	109,72±3,51	110,8±2,17	111,3±3,43	112,1±1,78

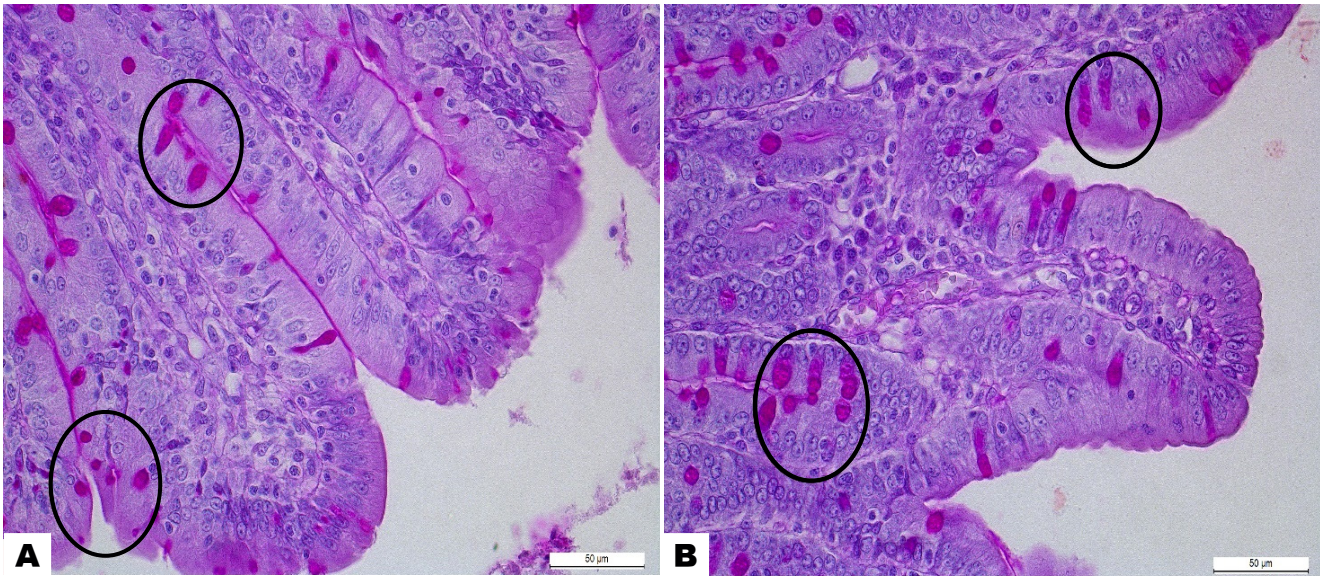

Fig. 1. Duodenal mucosa of piglets on day 14 of the experiment. A — control group, B — experimental group. Goblet cells are marked in a circle. PAS reaction

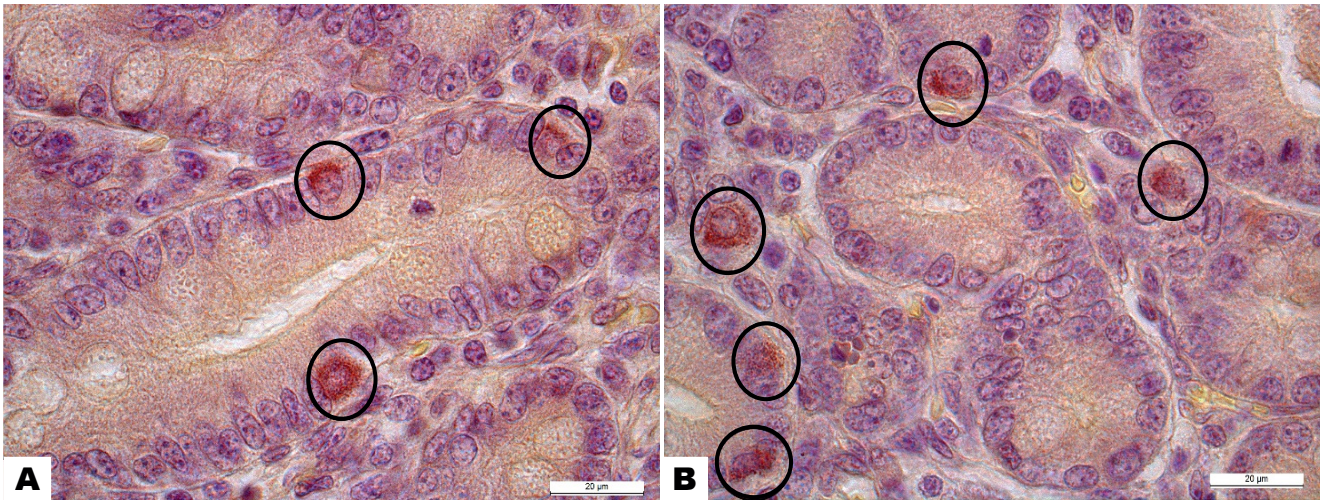

Fig. 2. Piglets' duodenum on day 14 of the experiment. a — control group, b — experimental group. Enterochromaffin cells are marked in a circle. Diazo staining method

The intestine performs a variety of functions, including providing a primary site for digestion and absorption of nutrients, as well as acting as a selective barrier against exogenous harmful substances. It is the integrity of the intestinal mucosa that is a key to the digestion and absorption of nutrients in piglets. Intestinal morphology, including villi height, crypt depth, and the ratio of villi height to crypt depth, clearly reflects the intestinal mucosa condition and its function. A decrease in villi height and crypt depth indicates a certain dysfunction of the mucous membrane, namely a decrease in its absorption capacity [32, 37]. Conversely, higher values of villi height and crypt depth indicate a better intestinal function. Changes in the structure of villi crypts are usually noted in weaned piglets.

Researchers described villi destruction, crypt hyperplasia, and intestinal mucosal atrophy, which destroyed the barrier function of the intestinal mucosa [13, 28, 30, 31]. For example, the study by Bomba et al. [3] 21 showed that 5 days after weaning (33 days of age), the villi height and crypt depth in the piglets' ileum were significantly lower than before weaning (28 days of age). Similarly, Hu et al. [14] showed that a decrease in villi height was caused by weaning, during which villi height and crypt depth were lower on days 3 and 7 after weaning, compared to the pre-weaning stage. In addition, Boudry et al. reported [4] that weaning stress caused long-term structural changes in the piglet ileum and villi height was still significantly lower on the 15th day than before weaning.

Additionally, it was shown that weaning stress caused a decrease in the relative weight of the small intestine, with the total weight on the 15th day after weaning being only 50% of the pre-weaning weight. Taken together, early

weaning and abrupt transition to roughage usually lead to morphological damage to the intestinal wall in piglets, namely a decrease in villi height, crypt depth, and relative intestinal weight. Therefore, in order to optimize the absorption of feed nutrients in piglets, it is necessary to minimize the impact of weaning stress.

Some morpho-functional differences in certain cytostructural and histostructural morphometric parameters of the duodenal wall in piglets during the neonatal and postnatal periods of development using the 'Globigen Jump Start' additive convincingly indicate a positive effect on mitigating the weaning stress. This was manifested by a decrease in the quantitative and linear indicators of histoarchitectonics of certain morphological components in the intestinal wall. It should be noted that the components of the feed additive have a positive effect on the synthesis of mucopolysaccharides, which is manifested by a significant increase in goblet endocrinocytes, especially in the experimental group.

It is known that mucins are synthesized mainly by goblet cells in the intestine [2, 16, 26]. Thus, any factors that affect goblet cell differentiation will also affect intestinal mucin secretion. Some authors report that weaning stress damages the differentiation of secretory cells, which leads to a decrease in mucin secretion [34, 38]. For example, Hedemann and Jensen [12] indicated that early weaning not only led to a decrease in intestinal mucin secretion, but also changed the structure of mucin glycosylation, weakening the function of the intestinal barrier and increasing the likelihood of developing intestinal infection.

Similarly, Yang et al. reported [38] that the MUC2 gene was negatively regulated in weaned piglets, suggesting that weaning stress destroyed barriers in the intestinal tract. Normal secretion and expression of mucins are essential for maintaining intestinal barrier function. When intestinal mucin secretion decreases, the mucosal layer of the intestinal mucosa becomes thinner and pathogens can easily pass through it. Moreover, those pathogens that compete with normal microflora on the intestinal mucosa surface for adhesion sites can destroy the normal microbial barrier. Finally, such pathogenic microorganisms as *Salmonella* and *Shigella* can destroy the mechanical barrier of the intestinal mucosa, inducing apoptosis of intestinal epithelial cells and disrupting the distribution of proteins between intestinal mucosal cells. In addition, changes in mucin secretion and expression can cause inflammation and damage the immune barrier of the intestinal mucosa [9].

Our studies have shown an increase in the number of goblet cells in the duodenum of piglets in the experimental group, both on day 14 and 28 of the experiment. Thus, on day 14, the number of goblet cells in the second experimental group increased by 4.71% compared to the control group, and by 1.79% on day 28, respectively. An increase in the number of enterochromaffin cells and the diameter of their nuclei in the experimental group indicated an increased synthesis of catecholamines and hormones, which had a very positive effect on the immune and physiological status of piglets, also emphasizing the crucial role of serotonin in neuronal metabolism and stress resistance formation.

The thickness of the duodenal wall muscle layer, in our opinion, increases due to the active peristalsis, which is enhanced by the action of some catecholamines, which are synthesized in a slightly larger amount under the influence of nutrients that make up the 'Globigen Jump Start' feed additive. The very fact of changes in the morphometric parameters of the villi height in the control group, namely a significant decrease on day 14, can be explained by a sharp change in the diet, which manifested itself morphologically and functionally. A slight change in the villi height on day 14 of the experiment should be considered a manifestation of the protective effect caused by the 'Globigen Jump Start' additive.

The increase in the crypt depth on day 14 indicates a high proliferative activity of enterocytes, slightly lower morphometric parameters in a control group indicate a lower proliferative activity, which was manifested by a decrease in the villi height, compared to the values obtained during the experiment. Analysing the indicators of crypt depth on day 28 in the control group of piglets, we can outline an interesting trend that was manifested by a slight increase in crypt depth, compared to day 14 of the experiment. This means the absence of the negative effect caused by weaning stress and the mild effect of switching to another feeding type, which provided the relative stability of linear morphometric parameters. Comparing the crypt depth in the control group between days 14 and 28, we revealed their increase, which is associated with the improved proliferative and regenerative activity of the epithelium. This should be regarded as a compensatory mechanism of a somewhat delayed type, compared to the experiment in which the following dynamics were observed: relative constancy of villi height and relatively stable morphometric parameters of crypt depth compared to day 14, which is a normal physiological condition for the intestinal mucosa under a minor feeding stress.

According to the results of histo-morphometric studies of the piglets' duodenal mucosa during different periods of postnatal and neonatal ontogenesis under the influence of the 'Globigen Jump Start' feed additive, a significant increase in the villi height was revealed in the experimental group, compared to the control one on day 14 by 37.42%, with the height's gradual leveling on day 28 of the experiment, indicating the mitigation of weaning stress.

The increase in morphometric parameters, namely, the number of enterochromaffin cells, goblet cells, and intestinal wall muscle thickness in piglets of the experimental group fed with the 'Globigen Jump Start' additive, compared to the control group, indicates an increased synthesis of catecholamines, hormones, and mucopolysaccharides, which positively affect the immune and physiological status of piglets stimulating their growth.

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Морфометричні особливості стінки дванадцятипалої кишки поросят у різні періоди постнатального та неонатального онтогенезу за впливу кормової добавки «Глобіген джам старт»

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Морфологічні параметри слизової оболонки тонкого відділу кишечника, такі як розміри ворсинок і крипт відіграють ключову роль у формуванні абсорбційної поверхні кишкової трубки. Кількість келихоподібних та ентерохромафінних клітин вказують на функціональний стан епітелію, стосовно секреції слизу та продукції катехоламінів та гормонів (серотонін, дофамін). Саме тому актуальним є вивчення та визначення окремих морфометричних показників стінки дванадцятипалої кишки поросят у різні періоди неонатального та постнатального розвитку, особливо в період стресу-відлучення та переходу на білковий тип годівлі. У статті представлені результати досліджень впливу кормової добавки «Глобіген джамп старт» на гісто-морфологічні параметри слизової оболонки дванадцятипалої кишки поросят на 7, 14 та 28 добу життя. Встановлено позитивний вплив на пом'якшення стресу-відлучення, що проявлявся зниженням кількісних та лінійних показників гістоархітектоніки окремих морфологічних компонентів кишкової стінки. Вірогідне збільшення келихоподібних ендокриноцитів, особливо в дослідній групі, позитивно впливало на синтез мукополісахаридів. Фізіологія шлунково-кишкового тракту поросят передбачає складну взаємодію між центральною нервовою системою, метасимпатичною нервовою системою, APUD-системою, ендокринною системою, за допомогою яких відбувається передача інформації за механізмами зворотного та прямого зв'язку в регулюванні функції шлунково-кишкового тракту. Збільшення кількості ентерохромафінних клітин, діаметру їх ядер в дослідній групі поросят вказувало на посилений синтез катехоламінів та гормонів, які вкрай позитивно впливають на імунний та фізіологічний статус поросят, а також надважливу роль серотоніну в нейрональному обміні та формуванні стресостійкості. Збільшення товщини м'язового шару стінки дванадцятипалої кишки, на нашу думку, відбувалось за рахунок активної перистальтики, що посилювалась під дією деяких катехоламінів, які синтезувались в дещо більшій кількості під впливом нутрієнтів, з котрих складається кормова добавка «Глобіген джамп стар».

Ключові слова: поросята, дванадцятипала кишка, ворсинки, крипти, келихоподібні клітини, ентерохромафінні клітини, дріжджі, яєчний порошок