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Morphology of the Digestive Canal Organs and Their Immune Formations in the Mulard Ducks

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Abstract. It is known that in the immune formations of the digestive canal of birds, which belong to the peripheral organs of hematopoiesis and lymphopoiesis, differentiation of T- and B-lymphocytes occurs under the influence of antigens that cause the development of specific (cellular and humoral) immunity. In this regard, the purpose of this study was to identify the features of the morphology of the digestive canal organs and their immune formations in ducks of the hybrid meat breed "Mulard" aged 150 days during puberty. During histological studies, pieces from different areas (oesophagus, parts of the stomach, intestines with Peyer's spots, Meckel's diverticula, and caecum diverticula) were selected, labelled, and fixed in a 10% aqueous solution of neutral formalin and poured into paraffin, according to the generally accepted method. Histological preparations were used to examine the features of the microscopic structure of the digestive canal organs and their immune formations and histotopography, the types of forms of lymphoid tissue were analysed, its area was calculated. It was established that the immune formations of the digestive canal organs of ducks are represented by all levels of structural organisation of lymphoid tissue, which are not equally expressed in certain parts of them. Accumulations of immune formations in the walls of the oesophagus and stomach are located in lamina propria plate of the mucous membrane and submucosal base, and in the intestines – also in the muscle membrane. Lymphoid tissue is best developed in the oesophagal tonsil, caecum diverticula, slightly less in the Meckel diverticula and Peyer's spots of the intestine. In the wall of the oesophagus and stomach of ducks, only minor accumulations of this tissue are observed. The results obtained on the morphofunctional state of peripheral organs of hematopoiesis and lymphopoiesis allow improving technologies for raising and exploiting birds to ensure their high viability and productivity

Keywords: poultry, oesophagus, stomach, intestines, lymphoid tissue, lymphoid nodules

Introduction

It is known that immune (lymphoid) formations are located in the walls of the digestive canal (tract) of birds, which are part of the peripheral organs of hematopoiesis and lymphopoiesis [1-3]. Knowledge of the morphofunctional state of these organs makes it possible to improve technologies for raising and exploiting birds to ensure their high viability and productivity.

Organised immune formations of the digestive canal of birds include tonsils (oesophagal, caecum), Meckel's diverticula, Peyer's spots [4-6]. Most of them are complex structures, the lymphoid tissue of which has a connection with the epithelium and may contain crypts. Immunocompetent structures also include some cellular elements (intraepithelial lymphocytes, plasma cells, macrophages, granulocytes) [7].

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A substantial content of immune formations is concentrated in the mucous membrane and submucosal base of the digestive canal organs [5]. Some of them are located inside it and are macroscopically invisible. In certain areas of the mucous membrane, these formations are very well developed, they can protrude in the form of rollers above the surface [8-10].

The functional basis of peripheral organs of hematopoiesis and lymphopoiesis, including immune formations, is formed by lymphoid tissue, effector cells, which recognise and neutralise antigens and clean the body from them [11; 12]. Thus, it is activated immediately after foreign agents enter the body during the feeding of birds.

The basis of lymphoid tissue is reticular tissue, which is a type of connective tissue. It is formed by reticular cells and intercellular substance. The fibres of the latter form a mesh-like structure. The cells of this grid contain lymphocytes. Reticular cells have a stellate shape, an oval nucleus, and long branched cytoplasmic appendages. The appendages of these cells are in contact and in some cases form dense adhesive contacts or desmosomes [13; 14].

In the structure and development of peripheral organs of hematopoiesis and lymphopoiesis, including immune formations, there are several patterns. The first is the beginning of their formation at the early stages of ontogenesis [15; 16]. Second is that they are always located in areas of possible penetration of foreign agents into the body and in places where they spread in it. The third is the gradual transformation of the structure of their lymphoid tissue, depending on the duration and intensity of exposure to antigens. In connection with the third pattern, there are four stages of differentiation in the development of lymphoid tissue.

At the beginning of the development of lymphoid tissue, a diffuse-scattered (associated) form of this tissue appears in the mucous membrane of internal organs. Its presence is considered as the readiness of the bird body to reproduce an adequate response to oral antigen intake in the intestine. The second stage is characterised by the fact that clusters of lymphoid cells are formed in the diffuse lymphoid tissue – pre-nodules that do not have clear borders. In the third stage, the formation of primary lymphoid nodules occurs, the appearance of which characterises the high morphological maturity of lymphoid tissue and peripheral organs of hematopoiesis and lymphopoiesis, that is, their readiness for the formation of lymphoid cells that provide immunity. The fourth stage is the development of lymphoid tissue. This is the stage of the highest degree of differentiation of the organs of the immune system. It forms lymphoid nodules with light centres (secondary). The formation of the latter is associated with an antigenic effect and indicates a highly protective reaction of the body. Some researchers [2] also distinguish the fifth stage, which is characterised by the disappearance of lymphoid nodules as a result of their reverse development during the age-related transformation of immune formations. Therewith, the area of diffuse lymphoid tissue decreases. In place of nodules, loose fibrous connective tissue grows noticeably, fat cells and lobules of adipose tissue appear. Thus, connective and adipose tissues displace the lymphoid parenchyma [1].

Given the important role of immune formations of the digestive system in the formation of immunity, their topography, microstructure and functional features are quite well investigated in chickens and certain species of wild birds [2; 5; 6]. In turn, in waterfowl, these data are incomplete, few, and contradictory.

The purpose of the study was to identify the structure of the digestive canal organs and morphofunctional features of their immune formations in 150-day-old Mulard Ducks.

Literature Review

Lykova & Kharchenko [17] identified a general pattern of localisation of immune formations in the wall of the digestive canal of birds. According to them, the greatest content of such formations is concentrated in the places of transition from one part of the digestive tube to another. Especially large numbers of them are located on the border between the oesophagus and the glandular part of the stomach, the small intestine, and the rectum. The number of immunocompetent cells increases with the onset of the sexual maturity of birds and then decreases with increasing age. In addition, the authors report that the intensity of the development of immune formations of the digestive organs of birds depends primarily on trophic specialisation and the method of obtaining food.

Khomish *et al*. [5] explain the substantial development of immune formations in the oesophagal wall of birds as compensation for the absence of the Pirogov-Waldeyer pharyngeal lymphoid ring, which is present in mammals. They are represented by scattered lymphoid nodules and the oesophagal tonsil. Lymphoid nodules are located along the entire oesophagus, but their aggregates are located in the thoraco-abdominal part of this organ near the secretory parts of the oesophagal glands. Their lymphoid cells substantially infiltrate the glandular epithelium.

Hanafy *et al*. [18] demonstrated that in ducks, the oesophagal tonsil is ring-shaped and grey-pink in colour. In the folds of the mucous membrane, this area, there is lymphoid tissue, which is represented by all levels of structural organisation (diffuse and pre-nodular forms, nodules without light and with light centres), which indicates its structural and functional maturity.

In the stomach of birds, immune formations are unevenly located in different parts of it. Their greatest content is located in the area of the sphincters of the intermediate zone and the pyloric part of the stomach, which regulate the flow of food entering the muscular part of the stomach and the duodenum, respectively [19]. To date, the immune formations of the stomach of chickens, especially its glandular part, are quite well investigated. They are located in the mucous membrane between the superficial tubular glands, in the lobules of the deep glands, and between them [20].

The intestinal wall with its immune formations of broiler Ducks of Blagovarsky cross in the age aspect is most fully investigated by Mazurkevych [6; 21]. According to the author, the duodenum and ileum contain one Peyer's spot, in the jejunum of ducks aged from one to 240 days there are three of them, in 330-day-olds – two, in 420-day-olds – one, in each caecum – 60-80 spots arranged in a chain. Feather spots are macroscopically detected from the age of 5 days of ducks and come in various shapes and sizes. Their size increases to 120-150 days of age. In the older bird, these indicators decrease. The Meckel diverticulum of ducks has the appearance of a tube with a narrowed tip, on which there may be a yellow sac residue by the age of

20 days of the bird. The length of the Meckel diverticulum increases to 150 days, and the width – to 120 days of age. By the 420-day age of ducks, these indicators decrease. Caecum diverticulae, as immune formations, are established up to 330 days of age in ducks. In the immune formations of the ducks' intestines, the author located early and mature B-lymphocytes, naive T-cells, T-helper cells, T-suppressors and natural killers, and in certain areas of it, ducks aged 180 days also have blood stem cells.

Materials and Methods

Classical methods of morphological research were used in the course of the study. All interventions and slaughter of ducks were conducted in compliance with the requirements of the "European Convention for the Protection of Vertebrates Used for Experimental and Scientific Purposes" (Strasbourg, 1986) [22] and the Law of Ukraine No. 692 "On the Protection of Animals from Cruelty" (3447-IV) of 02/21/2006 [23].

The material was obtained from six ducks of the hybrid meat breed "Mulard" aged 150 days. The birds were clinically healthy and demonstrated no signs of disease. The research was conducted based on the laboratory of the Department of Animal Anatomy, Histology, and Pathomorphology named after academician V.G. Kasyanenko of the National University of Life and Environmental Sciences of Ukraine during 2021-2022.

During histological studies, samples were cut out from various areas of organs (oesophagus, parts of the stomach, intestines with Peyer's spots located in them, Meckel's diverticulum, and Caecum diverticula were separated from the intestines where they are located). The samples were fixed in a 10% neutral formalin solution for 48 hours. Then they were washed with tap water for 24 hours and dehydrated with ethyl alcohol of increasing concentration (60%, 70%, 80%, 96%, and absolute alcohol). Before making the sections, the samples were sealed with paraffin. The resulting blocks (samples with paraffin) were glued to wooden blocks made of hard trees, from which sections with a thickness of 5-10 microns were cut on a special device – a sledge (skid) microtome. The obtained histological sections were stained with hematoxylin-eosin – to establish the general microstructure of the oesophagus, stomach and intestines and their immune formations, according to Mallory – to register collagen fibres of fibrous connective tissue and impregnated with a 1-2% solution of silver nitrate according to the Kelemen method – to detect reticular fibres. A drop of balsam was applied to the painted and impregnated sections and covered with a covering glass.

Histological preparations were investigated using Olympus and MBS-2 light microscopes. Features of the microscopic structure of the membranes of the wall of the digestive canal organs with their immune formations in ducks were determined, varieties of forms of lymphoid tissue and histotopography of immune formations were investigated. The area of lymphoid tissue was calculated by the "point counting" method using a binocular microscope and a measuring grid.

The results of the conducted studies were recorded in protocols, and their digital indicators were processed statistically using a computer using Excel. Individual histological preparations were photographed using an Olympus microscope with a Nikon Coolpix S3100 camera.

Results and Discussion

Morphology of the oesophagus and its immune formations

It is known that in the oesophagus of birds, two parts are distinguished by length: cervical (cranial) and thoraco-abdominal (caudal). True crop unlike chickens, is absent in waterfowl, instead there is a fusiform expansion [24; 25].

The mucous membrane of the oesophagus of ducks forms deep longitudinal folds (5-9), which facilitate the passage of food from the oral cavity to the stomach and has the ability to stretch. It is lined with a multi-layered flat partially keratinised epithelium, which directly near the glandular part of the stomach becomes thin and changes to a simple cylindrical glandular one. The lamina propria layer of the mucous membrane forms deep connective tissue papillae and is represented by loose connective and reticular tissues, where a large number of secretory parts of the oesophagal glands are located, the excretory ducts of which open on the surface of this membrane. The glands secrete mucus, which promotes the movement of food through the oesophagus. Bundles of smooth myocytes form a muscle plate of the mucous membrane, which is poorly developed and sometimes intermittent. Near the glandular stomach, the oesophagal glands disappear, and lobules of deep glands appear in the submucosal layer, which are characteristic of this stomach. The muscle membrane of the oesophagal wall is formed by separate layers of smooth muscle tissue. The inner (longitudinal) layers are attached to the submucosal base, and the outer (circular) layers are attached to the serous membrane. In some places, a longitudinal layer is also located outside the circular layer in this membrane. The inner layer takes part in the formation of high folds of the mucous membrane, going deeper into them. The adventitious membrane of the cervical oesophagus is formed by loose connective tissue. In the thoraco-abdominal part of this organ, it is replaced by a serous membrane, which has a similar structure but is covered with mesothelium.

The inner lining of the oesophagus of ducks contains minor accumulations of immune formations. In the lamina propria layer of this membrane, lymphoid elements are represented by small clusters of scattered lymphoid tissue, which are located under the epithelium, around blood vessels, in the wall of secretory parts of the oesophagal glands and their lumen, and less often it is located in the submucosal layer on the border with the muscle membrane. This tissue has no clear borders, it is uniform, without noticeable seals or rarefaction. It is based on reticular tissue, which has a mesh structure. Its loops contain lymphoid cells and macrophages. Lymphoid cells locally infiltrate the surface epithelium, epithelium of the secretory parts of the oesophagal glands, and their ducts. In addition to diffusely located lymphocytes, single lymphoid nodules are also located under the epithelium and near the oesophagal glands (Fig. 1). Some of them have light centres (reactive centres).

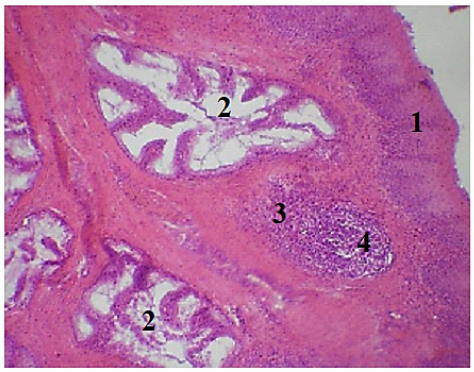


Figure 1. Duck oesophagus aged 150 days: 1 – epithelium; 2 – oesophagal glands; 3 – diffuse lymphoid tissue; 4 – secondary lymphoid nodule. Hematoxylin and eosin staining, ×63

Lymphoid nodules are mainly spherical and oval in shape with a well-defined membrane, in the formation of which reticular and collagen fibres take part. Primary lymphoid nodules are evenly filled with lymphoid cells. Reticular fibres in their central areas form grids with large cells. In lymphoid nodules with reactive centres, most lymphocytes are concentrated on the periphery and form a mantle zone. In the central areas of these nodules, reticular fibres disappear and are located only in the membrane and under it. The fibres are thicker, not tightly arranged, and do not form a grid.

According to the authors [26], activation, blasttransformation, proliferation, and antigen-dependent differentiation of B-lymphocytes into plasmocytes that are producers of specific antibodies of the IDA class takes place in the reactive centres of lymphoid nodules. When passing through epithelial cells, a secretory component is attached to the IgA and a secretory IgA (SIgA) molecule is formed. The latter provides protection (antiviral and antibacterial) on the surface of the mucous membrane.

In the area of the caudal part of the oesophagus, there are more immune formations. The surface epithelium of the mucous membrane in their places is infiltrated by lymphocytes, and perivascular immune formations are also recorded in the submucosal base. In the caudal part of the duck's oesophagus, during its transition to the glandular part of the stomach (oesophagal-gastric communication), lymphoid tissue is well developed and forms the oesophagal tonsil, which is consistent with the data of other authors [8; 10]. This immune formation is macroscopically visible and has the appearance of a ring-shaped strip with uneven edges, a folded and bumpy surface with a yellowish tinge.

According to [5], in the oesophagal tonsil of birds, which is macroscopically visible, the lymphoid tissue is located compactly, and in those species in which it is not detected – diffusely. In connection with this feature, they suggest classifying the oesophagal tonsils into compact and diffuse.

In the oesophagal tonsil of ducks, lymphoid tissue occupies almost the entire area of the lamina propria of the mucosal plate and submucosal base (Fig. 2).

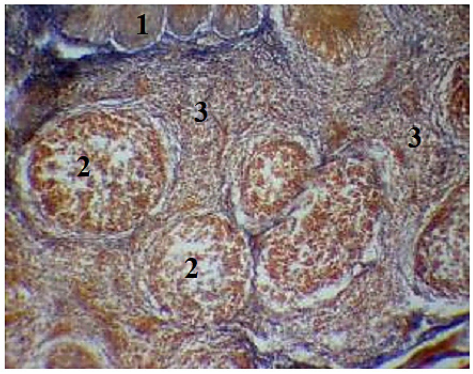


Figure 2. Oesophagal tonsil of a duck aged 150 days: 1 – superficial epithelium; 2 – secondary lymphoid nodules; 3 – diffuse lymphoid tissue. Mallory staining, ×90

It contains large lymphoid nodules and their precursors – pre-nodules, which are limited to accumulations of diffuse lymphoid tissue. Lymphoid nodules in the oesophagal tonsil are located mainly at the base of the folds of the mucous membrane, and substantial accumulations of diffuse lymphoid tissue are located at the tops of these folds. Nodules are mostly rounded and oval, less often ovate, pear-shaped, and irregular in shape. Crypt-like formations, which are well expressed on histopreparations, are limited to the layer of lymphoepithelium and open into the lumen of the oesophagal tonsil area. They are recorded on the side surfaces and at the base of the folds.

Morphology of the stomach and its immune formations

The stomach of birds is located between the oesophagus and intestines [21; 27; 28]. According to modern international anatomical nomenclature, it has three parts: glandular with its intermediate zone (Isthmus), muscular, and pyloric, which are not equally expressed in certain bird species [29].

The glandular part of the stomach of ducks has the appearance of a short fusiform (thick-walled) tube. Its anterior and posterior ends are narrowed, and the middle part is expanded. The muscular part of the stomach is located caudoventrally and is covered with accumulations of adipose tissue – a fat capsule. It has a disc-shaped shape and thick walls, on the lateral surfaces of which tendon mirrors are located and in the cranial and caudal parts blind sacs of the same name. The Isthmus of the glandular part of the stomach opens into the cranial blind sac. Next to it is the pyloric part of the stomach – the exit to the duodenum.

The mucous membrane of the glandular part of the stomach of ducks is the thickest. It is covered with a simple cylindrical glandular epithelium. Numerous surface glands permeate the lamina propria layer of this membrane. According to the authors [19; 28], these glands produce a viscous secret that has bactericidal properties. In the mucous membrane, the muscle plate is represented by bundles of longitudinally oriented smooth myocytes. In some places, it is intermittent. In the submucosal layer of the glandular part of the stomach of ducks, deep complex glands are located, a characteristic feature of which is a complex system of excretory ducts. The glands are grouped into lobules, which are arranged in one or two rows and have a predominantly polygonal shape.

According to some authors, the secretory parts of deep complex glands are formed by glandulocytes of the same type and combine the secretion of pepsinogen and hydrochloric acid, which gave reason to call them oxinto-peptic [21]. Their excretory ducts open with papillae on the surface of the mucous membrane. In the area of the intermediate zone, there are no deep glands.

The muscular membrane of this part of the stomach of ducks is three-layered and is represented by two longitudinal (inner and outer) and circular (middle) layers. In the muscle membrane, between its layers, layers of loose connective tissue are noticeable, in which blood vessels and nerve plexuses pass.

The mucous membrane of the muscular part of the stomach is covered with a simple cubic epithelium. The lamina propria layer of this membrane contains gastric glands, the secret of which covers the entire surface of the mucous membrane with a dense pellicle – the cuticle. The latter protects it from mechanical damage. It also contains a lot of collagen fibres that do not have a specific orientation. The muscle plate is absent. The submucosal base is well defined. It is formed by dense fibrous connective tissue. The muscle membrane of this part of the stomach is best developed and formed by muscle tissue, which forms two groups of powerful smooth muscles: intermediate and lateral. The intermediate muscles are located in the area of the blind sacs, and the lateral muscles lie on the body of the stomach and form its edges.

The pyloric part of the stomach of ducks is similar in structure to the muscular one, but the cuticle on the mucous membrane is weakly expressed, and the muscle membrane is thinner and consists of two layers of smooth myosites: internal-circular and external-longitudinal. However, a muscle plate appears in the mucous membrane of this part of the stomach. It is formed by fragmented bundles of smooth muscle cells.

Immune formations are unevenly located in different parts of the stomach of ducks. They are best expressed in the glandular part of the stomach (Fig. 3).

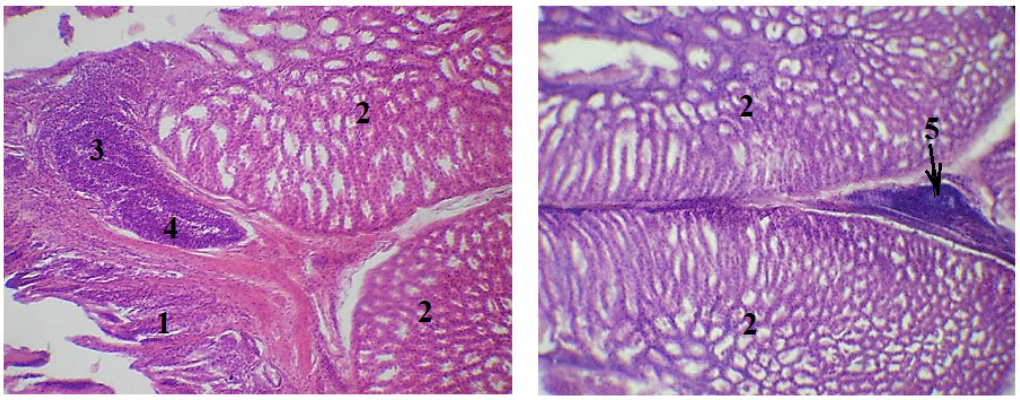


Figure 3. Glandular part of the stomach of a duck aged 150 days: 1 – superficial tubular glands; 2 – lobules of deep glands; 3 – diffuse lymphoid tissue; 4 – secondary lymphoid nodule; 5 – primary lymphoid nodule. Hematoxylin and eosin staining, ×63

Immune formations are mainly located at the base of the folds of the mucous membrane between and under the surface tubular glands. In places of these accumulations, the structure of the mucous membrane's lamina propria changes. It registers collagen and reticular fibres. The latter intertwine in different areas and form a small-cell grid, the cells of which contain lymphoid cells and macrophages. The nature of the structure of the surface and glandular epithelium of the mucous membrane also changes. Locally, due to infiltration by lymphoid cells, it becomes spongy. Diffuse lymphoid tissue and lymphoid nodules are also recorded in and between the lobules of the deep glands. Their lymphoid cells enter the glandular epithelium of the lobules. Single lymphoid nodules are located in the fibrous connective tissue of the submucosal base, which is located near the muscle plate of the mucous membrane. Some accumulations of diffuse lymphoid tissue of the submucosal base can connect to those of the mucous lamina propria plate. Single rounded lymphoid nodules are also located in the subserous base of the serous membrane.

In the intermediate zone, immune formations are localised mainly in areas close to the glandular part of the

stomach. They are located in the lamina propria layer of the mucous membrane and less often in the submucosal base. In lamina propria, accumulations of lymphoid tissue are located between the tubular glands and at their base. Nodules are placed mainly singly. Some of them bend the muscle plate, violating its integrity.

In the mucous membrane of the muscular and pyloric parts of the stomach, immune formations are poorly developed and are represented by a diffuse form of lymphoid tissue and single secondary round lymphoid nodules. They are located between the tubular glands in the lamina propria of this membrane. The epithelium of the mucous membrane at the sites of immune formations is infiltrated by lymphoid cells. These same cells also infiltrate the tubular glands.

Morphology of the intestine and its immune formations

The small intestine of birds consists of the duodenum, jejunum, and iliac, and the colon – two blind and rectum, which ends in the cloaca. Among the components of the small intestine, the jejunum is the longest, the duodenum is much shorter, and the ileum is the shortest [6; 30].

The intestinal mucosa of ducks is well developed. It forms villi, crypts, and folds. In the small intestine, the villi are high and thin, and in the large intestine – low and wide. The epithelium of the villi is simple cylindrical bordered. Between its cells are bordered and goblet-shaped. Border cells have a cylindrical shape, on their apical pole there are microvilli. It is characterised by the appearance of a thin line on the surface of these cells. The border increases the absorption surface of the intestine.

Goblet cells are known to be single-celled glands that produce mucus. The latter covers the epithelial layer of the mucous membrane [28]. They have a goblet shape. Their apical pole is expanded and filled with large granules of light (mucosal) secretions. The number of such cells increases in the distal parts of the intestine.

The surface epithelium goes deeper into the lamina propria layer of the intestinal mucosa and forms numerous intestinal glands of various depths. It is known that undifferentiated epithelial cells are located at their bottom, which are stem cells for the epithelium. The lamina propria layer of the mucous membrane is formed by loose connective tissue, which contains reticular and collagen fibres. It also has many vascular plexuses. The muscle plate of the mucous membrane is located between the lamina propria layer and the submucosal base. It is weakly expressed and is represented by bundles of smooth myocytes. The submucosal base has the appearance of a thin layer of loose connective fibrous tissue, contains numerous blood vessels and nerve plexuses.

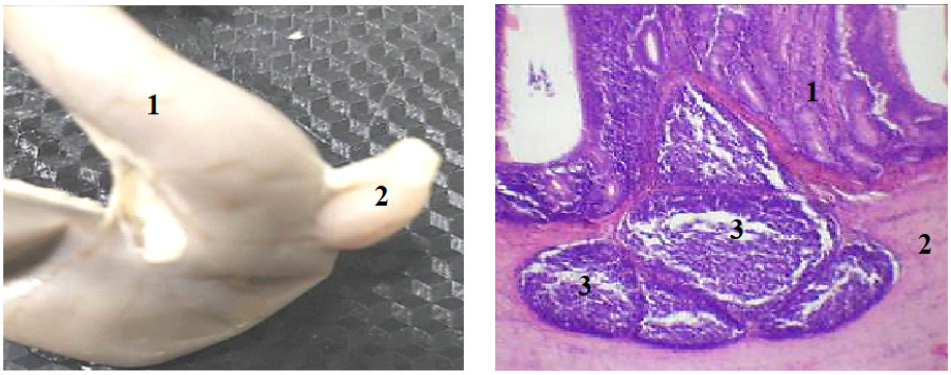
The muscular lining of ducks' intestines is formed by two layers of smooth muscle. The inner (circular) layer is better developed than the outer longitudinal one. In the duodenum, this membrane is three-layered: the outer and inner layers are longitudinal and the middle one is well developed – circular. Loose connective tissue with blood vessels and nerve nodes is contained between the layers of the muscle membrane and bundles of smooth myocytes.

In the intestinal wall of ducks, Meckel's diverticulum, Peyer's spots, and two glaucous diverticulae are registered among the immune formations. Unlike other birds, ducks do not have pronounced caecum tonsils, which is consistent with the data of other authors [6].

Peyer's spots are located in the wall of the small intestine and caecum. They are not detected in the rectum. The spots are visible visually without the use of special methods and have a lighter colour, a thinned bumpy wall and a spongy-porous appearance due to the numerous holes of the crypts. One such spot was located in the duodenum and ileum, and 3-4 in the jejunum. The largest number of spots is located in the caecum – 27-46. They are round, oval, and conical in shape.

Meckel's diverticulum is a remnant of the yolk sac duct. It is visible in ducks in the form of a pear-shaped protrusion on the antimesenteric surface of the jejunum, and its tip is directed cranially (Fig. 4A). The caecum of ducks on its cone-shaped tips contains lymphoid tissue that forms apical caecum diverticula. The latter have a lighter colour compared to other areas of the caecum.

Some authors explain the presence of well-developed lymphoid tissue in Peyer's spots and caecum diverticula by colonising them with urea-processing bacteria [9]. In all immune formations of the duck intestine, the lymphoid tissue is morphofunctional mature and is represented by a diffuse form and secondary lymphoid nodules (Fig. 4B, 5, 6). Pre-nodules and primary lymphoid nodules occur only on certain histoses of these structures. It is located mainly in the villi, between the crypts and in the submucosal base. In the areas where the lymphoid tissue is located, thickening of the mucous membrane is observed. In some places, it deapens between the surface bundles of smooth myocytes of the circular layer of the muscle membrane. That is, lymphoid tissue is located not only in the mucous membrane, but also in the muscular lining of the intestines of ducks. Lymphoid cells of this tissue locally infiltrate the villi epithelium and crypts. Such infiltration leads to the formation of lymphoepithelium. Primary and secondary lymphoid nodules are mostly elongated-oval, triangular (with a wide base), and rounded in shape. Reticular fibres in nodules have the greatest thickness in the membrane, giving them shape. Usually, secondary lymphoid nodules are larger than primary ones.



A B

Figure 4. Meckel diverticulum of the duck's empty intestine at the age of 150 days: A. Macropreparation: 1 – Jejunum; 2 – Meckel's diverticulum. B. Histopreparation:1 – mucous membrane; 2 – muscle membrane; 3 – secondary lymphoid nodules. Hematoxylin and eosin staining, ×90

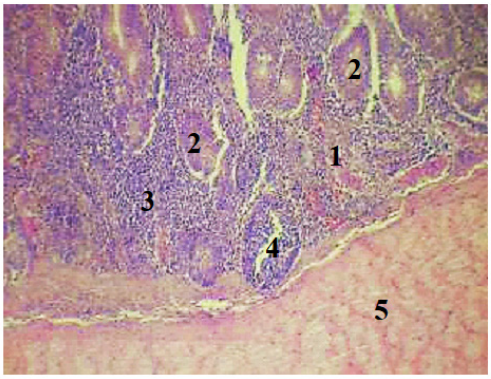


Figure 5. Peyer's spot of 12-duodenum of a duck aged 150 days: 1 – mucous membrane; 2 – crypts; 3 – diffuse lymphoid tissue; 4 – secondary lymphoid nodule; 5 – muscle membrane. Hematoxylin and eosin staining, ×63

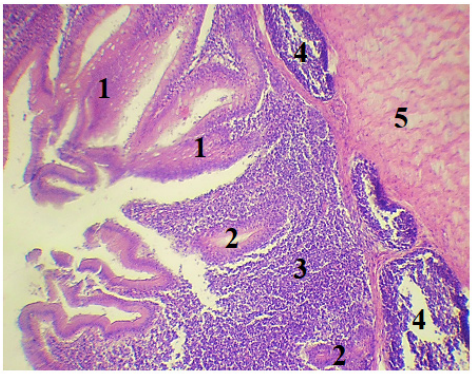


Figure 6. Apical caecum diverticulum of a duck aged 150 days:1 – villi; 2 – crypts; 3 – diffuse lymphoid tissue; 4 – secondary lymphoid nodules; 5 – muscle membrane. Hematoxylin and eosin staining, ×63

Lymphoid nodules are not equally located in the mucous and muscular membranes. In the mucosa – they are localised mostly perpendicular to the surface, and in the muscle-parallel to the bundles of gdad myocytes. Nodules are arranged singly, in pairs, or in larger groups. In the diverticulum of Meckel ducks, secondary lymphoid nodules are located behind the entire plane of lamina propria of the mucous membrane and submucosal base, and in the muscle membrane, they are deepened in a circular layer and placed in groups. In Peyer's spots and caecum diverticula, lymphoid nodules are arranged in a chain in the muscle membrane at the border with the submucosal base.

Content of lymphoid tissue in the digestive system

As noted above, lymphoid tissue forms the basis of immune formations. In the walls of the digestive canal organs, it occupies a different area (Table 1).

Table 1. Area of lymphoid tissue in the walls of the digestive canal of ducks aged 150 days, %, m ± m, n = 6

Organs and their parts	Area of lymphoid tissue
Cervical oesophagus	5.45 ± 0.32
Thoraco-abdominal part of the oesophagus	6.39 ± 0.72
Oesophagal tonsil	61.22 ± 0.65
Glandular part of the stomach	19.18 ± 0.21**
Intermediate zone of the glandular part of the stomach	22.34 ± 0.27**
Muscular part of the stomach	3.14 ± 0.56
Pyloric part of the stomach	5.63 ± 0.23*
Peyer's spots 12-duodenum	38.32 ± 0.87
Peyer's empty bowel spots	44.28 ± 0.77

Table 1, Continued

Organs and their parts	Area of lymphoid tissue
Peyer's spots of the ileum	55.12 ± 0.89
Peyer's caecum spots	36.55 ± 0.58
Meckel's Diverticulum	49.45 ± 0.92
Coccygeal diverticula	62.21 ± 0.39

Note: * P < 0.01, compared to the muscular part of the stomach; **P < 0.001, compared to the muscular and pyloric parts of the stomach

As can be seen from the data in Table 1, the smallest area of lymphoid tissue is occupied in the cervical and thoraco-abdominal parts of the oesophagus, the muscular and pyloric parts of the stomach. Therewith, the content of this tissue in the thoraco-abdominal part of the oesophagus is 0.94% higher than in the cervical part of this organ, and in the pyloric part of the stomach – by 2.49% (p<0.01), from its muscular part. A large area of lymphoid tissue is recorded in the glandular part of the stomach and its intermediate zone, respectively, by 16.04% (p<0.001) and 19.2% (p<0.001), compared with the muscular part of the stomach, and by 13.55% (p<0.001) and 16.71% (p<0.001) – with the pyloric part of the stomach. It is located locally in the mucous membrane and submucosal base of these organs and their parts. A substantial content of lymphoid tissue is observed in immunocompetent structures – tonsils, diverticula and Peyer's spots in the intestines of ducks. The largest area of lymphoid tissue was recorded in the diverticula and oesophagal tonsil (over 60%) and slightly smaller in Peyer's bowel spots and Meckel's diverticula (35-55%). Therewith, as noted above, the lymphoid tissue in the oesophagal tonsil is located in the mucous membrane and submucosal base of this area of the oesophagus, and in the immune formations of the intestine, it is also well expressed in the muscle membrane.

Conclusions

Immune formations of the digestive organs of ducks are associated with the mucous membrane and submucosal base, in the intestines, they are also located in the muscle membrane. Some of them are macroscopically invisible. In certain areas, they are well developed and protrude above the surface of the mucous membrane and have specific names (tonsils, Peyer's spots). The basis of immune formations is formed by lymphoid tissue, which in the organs of the digestive canal of ducks is morphofunctional mature and is represented by a diffuse form, primary and secondary lymphoid nodules, which are not equally expressed in certain parts of them.

Diffuse lymphoid tissue has no clear borders, and the membranes in the lymphoid nodules are well defined. Most nodules have light centres that are formed as a result of antigenic stimulation. Lymphoid tissue is best developed in substantial immunocompetent structures (oesophagal tonsil, caecum diverticula, Meckel diverticula, and Peyer's intestinal spots). In the wall of the oesophagus and stomach of ducks, only minor local accumulations of it are located.

It is important to consider the results obtained when raising and operating this poultry, which will ensure the formation of an appropriate level of specific immunity.

Further studies should be aimed at investigating the morphological features of the digestive canal organs and their immune formations in Mulard ducks in the age aspect.

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Морфологія органів травного каналу та їхніх імунних утворень в качок породи «Мулард»

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Анотація. Відомо, що в імунних утвореннях травного каналу птахів, які відносять до периферичних органів гемопоезу та лімфопоезу, відбувається диференціація Т- та В-лімфоцитів під впливом антигенів, які зумовлюють розвиток специфічного (клітинного і гуморального) імунітету. У зв'язку з цим, метою цього дослідження було з'ясувати особливості морфології органів травного каналу та їх імунних утворень у качок гібридної м'ясної породи «Мулард» віком 150 діб на період статевої зрілості. Під час проведення гістологічних досліджень шматочки з різних ділянок (стравоходу, частин шлунка, кишок із розташованими в них плямками Пейера, дивертикул Меккеля та сліпокишкові дивертикули) відбирали, етикетували та фіксували у 10 % водному розчині нейтрального формаліну і заливали в парафін, відповідно до загальноприйнятої методики. На гістологічних препаратах вивчали особливості мікроскопічної будови органів травного каналу та їхніх імунних утворень і гістотопографію, досліджували різновиди форм лімфоїдної тканини та підраховували площу цієї тканини. Встановлено, що імунні утворення органів травного каналу качок представлені всіма рівнями структурної організації лімфоїдної тканини, які неоднаково виражені в певних їхніх частинах. Скупчення імунних утворень в стінках стравоходу і шлунка розташовані у власній пластинці слизової оболонки та підслизовій основі, а в кишечнику – ще й у м'язовій оболонці. Найкраще лімфоїдна тканина розвинена у стравохідному мигдалику, сліпокишкових дивертикулах, дещо менше у дивертикулі Меккеля та плямках Пейєра кишечника. У стінці стравоходу та шлунка качок спостерігаються лише незначні скупчення цієї тканини. Отримані результати щодо морфофункціонального стану периферичних органів гемопоезу та лімфопоезу дають можливість удосконалювати технології вирощування і експлуатації птахів з метою забезпечення їхньої високої життєздатності та продуктивності

Ключові слова: свійська птиця, стравохід, шлунок, кишечник, лімфоїдна тканина, лімфоїдні вузлики