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Histochemical Structure of the Nasal Concha Mucosa in Ducks (*Anas plathyrinchos*)

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ABSTRACT

Background: Due to their morphological and structural characteristics, birds possess a respiratory system distinct from that of mammals. Their nasal structures are highly specialized respiratory tissue sections designed. In these animals, the cartilaginous conchae exhibit a helical morphology. This special structure enables efficient heat exchange and moisture transfer.

Methods: The nasal cavity ducts were removed and routine histological procedures were performed in Carnoy fixative. Triple staining technique was applied to sections to determine the histological structure. PAS, PAS-diastase, Alcian Blue-PAS, Alcian Blue-Aldehyde Fuchsin and Best Carmin stainings were applied to determine the mucin content of the glands.

Result: Histological examination revealed that it was lined by squamous keratinized epithelium, which formed tubular glands containing secretory epithelium. A large amount of Grandry and Herbst corpuscles were found. The cartilage in the concha showed convoluted, were covered by pseudostratified prismatic epithelium. Unlike mammals, alveolar glands were found instead of goblet cells. It was determined that the intraepithelial glands in carboxylic acid mucin and neutral mucin. Acid mucins in the concha mucosa, while neutral mucins were in the alveolar glands. No difference was observed in the PAS staining of in the concha, while glycogen in concha and the Bowman glands were found not to contain mucin.

Key words: Duck (*Anas platyrhynchos*), Function, Histochemistry, Histology, Nasal concha.

INTRODUCTION

Due to their morphological and structural characteristics, birds possess a respiratory system distinct from that of mammals. Their nasal structures are highly specialized respiratory tissue sections designed to warm and humidify air during respiration. In these animals, the cartilaginous conchae exhibit a helical morphology. This special structure increases the contact area between the air and the mucosal surface during respiration, enabling efficient heat exchange and moisture transfer (Geist, 2000).

The nasal cavity, with its rich vascular network and large surface area, is considered one of the most suitable sites for mucosal vaccination methods developed as an alternative to parenteral administration. It is also considered an important anatomical and immunological site due to its frequent use in poultry vaccination (Kang *et al*., 2013).

Respiratory system diseases in poultry constitute an important disease group due to their prevalence and the economic losses they cause. A large proportion of the serious infections encountered, especially in laying hens and broiler flocks, originate in the respiratory system (Matham *et al*., 2022; Ponnusamy *et al*., 2019; Shankar, 2008). The mucosa of the nasal cavity, which constitutes the initial section of the respiratory system in mammals and poultry and is connected to the external environment through the nostrils, is suitable for the development of a large population of microorganisms called the “nasal flora”. The types of microorganisms found in the nasal flora may vary by animal species and geographic region. These microorganisms can be transported to the bronchi and lungs along with inhaled air, but under normal conditions, they are rapidly eliminated by the respiratory system’s effective defense mechanisms (López, 2009).

The defense mechanisms of the respiratory system consist of specific and nonspecific components. Specific defense elements located in the nasal cavity are mechanisms that occur through mucosa-associated lymphoid tissues (*e.g*., NALT and BALT), involving cellular and humoral immune responses (Kang *et al*., 2013; Manimaran *et al*., 2019). Nonspecific defense mechanisms, on the other hand, involve physical and mechanical processes based on filtering inhaled air and removing particles, particularly in the air-conducting sections such as the nasal cavity, trachea and bronchi. The main processes are: air vortex formation, centrifugal force effect; particle trapping, mucus trap and mucociliary clearance mechanisms. The first line of protection against inhaled particles occurs in the nasal cavity, where air vortices and centrifugal force are created by the curved structure of the nasal conchae (also known as the ‘nasal respiratory

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turbinate). The mucosal epithelium of the air-conducting respiratory tract is pseudostratified and prismatic in nature, with its surface lined by ciliated cells. The mucosal epithelium in the air-conducting respiratory tract is pseudostratified prismatic in nature and its surface is lined with ciliated cells. This covering epithelium contains goblet cells as well as quinociliated cells. The mucus secreted by the glands and goblet cells in the submucosa combines to support important defense mechanisms, including particle retention, mucus trap formation and mucociliary clearance. Particles larger than 10 µm in diameter strike the mucosal surface due to the centrifugal force generated during airflow in the turbinates. They are then trapped by the layer of mucus covering the quinciliated epithelium. These trapped particles are quickly removed by a system known as the 'mucociliary escalator', consisting of the coordinated movement of ciliated cells and a thin layer of mucus (López, 2009). Ducks, belonging to the genus Anas within the family Anas platyrhynchos domesticus, are among the poultry species domesticated by humans in the early periods. It is generally accepted that the domestication of ducks began approximately 4000-5000 years ago, particularly in Asia, with a focus on China and other regions; however, some researchers suggest that this process may extend to even earlier periods. Ducks, adaptable to both hot and cold climates, are raised in many parts of the world in various breeds and varieties. Therefore, they possess a wide range of ecological adaptation capabilities. Infections such as viral enteritis (duck plague) in ducks can lead to high morbidity and mortality, causing significant economic losses. However, with appropriate care and biosecurity measures, many infections can be controlled more effectively than in other poultry species (Dhama *et al*., 2017; Liang *et al*., 2022).

In a study he conducted, Choudhary (2025) highlighted that animal models have enabled researchers to examine the feasibility, risks and potential outcomes of new surgical techniques, thereby leading to improved patient safety and better surgical outcomes. He noted that small animal models are widely used in surgical research, whilst large animal models offer advantages in physiological and anatomical studies. In this study, ducks were also selected as the small animal model.

Advances in animal anatomy teaching models herald a significant transformation in veterinary anatomy education, offering innovative alternatives and complementary elements to traditional dissection-based methods. Ranging from plastinated specimens to silicone replicas and from 3D-printed models to virtual simulations, these models enhance clarity, accessibility and ethical suitability in the transmission of anatomical knowledge (Choudhary and Sarkar, 2025). To this end, we plan to produce a 3D-printed model in our future studies to facilitate a better understanding of the nasal concha.

Numerous studies have been published on the histomorphology of the nasal cavity in various species of poultry, including grouse (Yokosuka *et al*., 2009), the rooster (Taşbaş *et al*., 1994), quail (Çevik-Demirkan *et al*., 2007), duck (Dar *et al*., 2014; Kang *et al*., 2014) and chicken (Kang *et al*., 2013; Bang and Bang, 1969). However, studies on the histochemical properties of the nasal cavity are limited and only one study on chickens (Bang and Bang, 1969) has been found. A study on ducks has also been conducted. Histological and histochemical characteristics of larynx, trachea and syrinx tissues in ducks (Al-Ahmed and Sadoon, 2020), embryological development of the turbinate (Dar *et al*., 2014) and tracheal cell organization (Mokhtar and Hussien, 2020) have been studied; however, no studies on nasal turbinates have been found. The aim of this research is to elucidate the histological features of nasal turbinate mucosa in ducks, a subject that has not been studied in detail to date and also to clarify the form-function relationship of nasal turbinates in a relatively disease-resistant poultry species by determining the histochemical characteristics of the goblet cells and glands found in the mucosa. Mucins in the respiratory system are large, elongated glycoprotein molecules with a high carbohydrate content and play an important role in host defense mechanisms. Spicer (1965); Lepi (1968) and Stoward (1967) introduced the concept of 'mucosubstance', which is used to define carbohydrate-rich compounds apart from glycogen that are found in the excretions of certain epithelial formations or in connective tissue. According to this classification, mucosubstances found in connective tissue are called "mucopolysaccharides," while mucosubstances secreted by epithelial cells are called "mucin," a type of mucous glycoprotein. Mucins are classified into two main groups: neutral and acidic. Neutral mucins exhibit slightly alkaline properties and help reduce the toxic effects of various substances and balance the pH of the environment. Acidic mucins are divided into two subgroups: weak and strong acidic. Weakly acidic mucins contain a terminal carboxyl group and are called "carboxylic mucin" or "sialomucin." These mucins contain chelating agents and exhibit antibacterial and antiviral properties. Strongly acidic mucins are called "sulfomucins" because they contain a sulfate group. Thanks to their thick and viscous structure, they form a protective layer that provides lubrication (Spicer, 1965; Stoward, 1967). Furthermore, the integration of artificial intelligence into veterinary education makes the educational content more accessible, whilst enriching the learning environment by introducing a range of innovative approaches to the study of anatomy, thereby comple menting traditional teaching methods (Choudhary *et al*., 2025).

MATERIALS AND METHODS

The study presented here was conducted on 10 healthy, mature ducks obtained from a breeder in the Elbistan district of Kahramanmaraş Province. The *in vitro* study was conducted in the Histology Department Laboratory of the Faculty of Veterinary Medicine, Harran University, Şanlıurfa,

Turkey. This study was conducted between October 2025/ March 2026.

Study design

After the ducks were killed by decapitation by the breeder, the duck heads were placed in Carnoy solution and taken to the Histology-Embryology Department laboratory of Harran University Faculty of Veterinary Medicine. There, the right and left nasal turbinate sections of the ducks were removed by dissection, placed back in Carnoy solution and fixed for 6 hours. Then, without washing, they were dehydrated starting with a 96% graded alcohol series, passed through methyl benzoate-benzol series and blocked in paraplasts. Serial sections approximately 6 µm thick were taken from the prepared blocks and the first of these sections was stained with Mallory's triple staining technique, modified by Crossmon, to reveal the general structure of the tissue.

Sample processing

Serial sections of approximately 6 ìm thickness were taken from paraffin blocks to determine the histochemical composition of the mucin content of the glands in the nasal concha mucosa using the following staining methods:

1. **Phenylhydrazine-PAS:** To identify neutral mucins and periodate-reactive acid mucins in the glands.
2. **Best carmin:** To identify glycogen in the glands.
3. **PAS:** To show glycogen and other periodate-reactive carbohydrates.
4. **PAS-diastase:** To detect the presence of sialidase-sensitive glycogen.
5. **Alcian blue (pH. 2.5)-PAS:** To show neutral and acid mucins in the glands.
6. **Alcian blue (pH. 2.5)-Aldehyde Fuchsin staining methods:** To differentiate carboxylated and sulfated acid mucins in the glands.

The stained preparations were examined using an Olympus DP71 (Japan) research microscope and photographed with a BX51 (Japan) digital camera.

RESULTS AND DISCUSSION

Histological results

Rostral concha section

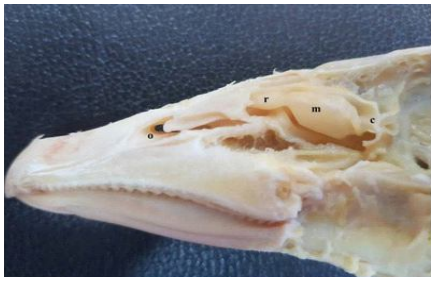
In ducks, the nasal passage is formed of two separate compartments, one on the right and one on the left, which are divided by a septum. Each compartment contained distinct rostral, middle and caudal conchae with well-defined boundaries and skeletons made of hyaline cartilage (Fig 1).

The rostral concha was observed to have a long, narrow, conical structure with it is tip directed towards the nostrils and a slight inward curve. Examination of sections stained with triple staining revealed that the first mucosal section of the rostral concha, beginning immediately after the nostrils, was covered with stratified squamous keratinized epithelium without microscopic papillae (Fig 2A, arrow). As the area progressed deeper, the keratin layer disappeared and the stratified squamous epithelium formed prominent microscopic papillae, creating a columnar appearance (Fig 2A). Furthermore, it was found that these columnar structures transformed into tubular intraepithelial glands, forming crypt-like invaginations (Fig 2B, arrow), with their bases consisting of cells resembling mucous gland epithelium (Fig 2A, arrows).

Many grandry bodies were detected within the lamina propria at the entrance of the rostral concha, located close to the epithelium. These bodies were determined to consist sometimes of a single and sometimes of multiple specialized cells. The long and oval-shaped cells were observed to be arranged parallel to the epithelium within the body (Fig 3A). Herbst bodies were also detected in the same region, albeit in smaller numbers (Fig 3B).

Middle concha section

The middle concha constituted the widest part of the nasal cavity in the duck. The cartilaginous structure of this concha showed a lamellar arrangement that coiled helically towards the lumen and this coil formed two complete and one half-ring (Fig 4A). The cartilaginous surface was determined to be covered with pseudostratified, kinociliated prismatic epithelium. Although a small number of goblet cells were found among the epithelial cells, in the duck,



Rostral concha (r); Middle concha (m); Caudal concha (c).

Fig 1: Macroscopic observation of the nasal concha.

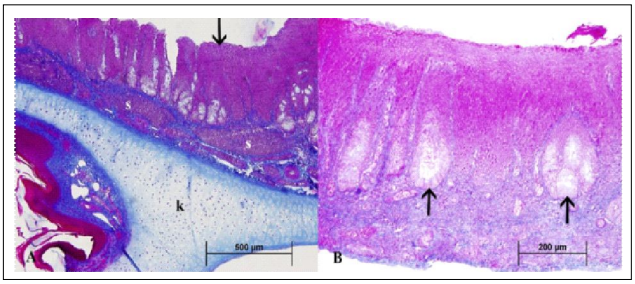


Fig 2: A. The entrance of the rostral conchae. Non-keratinized stratified squamous epithelium (arrow), Hyaline cartilage (k), solitary lymphoid follicles (s). **B.** Deep part of the rostral concha. Intraepithelial mucous glands (arrows). Triple staining.

these were replaced by numerous intraepithelial gland structures formed by the aggregation of mucous secretory epithelial cells. These glands were in the form of shallow, single-row alveolar glands in the mucosa where the lamina propria was narrow and especially on the concave surfaces of the rings; while in the convex regions where the connective tissue was wider, they were in the form of deeper, 2-3 row tubulo-alveolar gland structures (Fig 4B). It was determined that vascularization was increased in the lamina propria and solitary lymph follicles were present in the transition zones of the conchae. Furthermore, aggregate lymph follicles belonging to NALT were observed, generally on the concave surface of the innermost ring of the middle concha (Fig 4B).

In the region where the middle concha transitions to the caudal concha, it was found that the respiratory epithelium was placed by the olfactory epithelium; and the intraepithelial mucous glands were replaced by serous Bowman's glands located in the lamina propria. It was also determined that these two concha segments were interconnected. It was noted that the Bowman's glands, stained pink, exhibited serous secretion. Solitary lymph follicles were observed on the concave surface of the concha cartilages in the transition zone (Fig 5A, B).

Caudal concha section

When the panoramic view obtained in the longitudinal section of the caudal concha was evaluated, it was determined that the cartilaginous extensions exhibited a convoluted structure forming two separate chambers and a triangular area was formed between these extensions (Fig 6A). It was determined that the inner surface of the chambers was covered with olfactory mucosa, while the triangular area in the inner part was covered with respiratory epithelium containing only goblet cells and no intraepithelial gland structures. Three different cell types were observed in the olfactory epithelium. It was determined that the cells with their nuclei in a single row and located in the basal region were basal cells; the cells with a prominent nucleolus, euchromatic nuclei and acidophilic cytoplasm were supporting cells; and the cells located closer to the surface, with euchromatic nuclei and pale cytoplasm were olfactory cells (Fig 6B).

Histochemical results

Rostral concha section

As a result of PAS staining, a positive reaction was detected in the apical cytoplasmic regions of the intraepithelial glands located in the rostral concha. This suggests the presence of glycogen or a mucosubstance, such as sulfated mucin or sialomucin (Fig 7A). To determine whether this content was glycogen, PAS-Diastase and Best Carmine staining methods were applied to successive sections; however, in the examination with both methods, no evidence of glycogen was found in any concha section. In the PH-PAS technique applied to another successive section, a weak reaction was observed in the parts of the

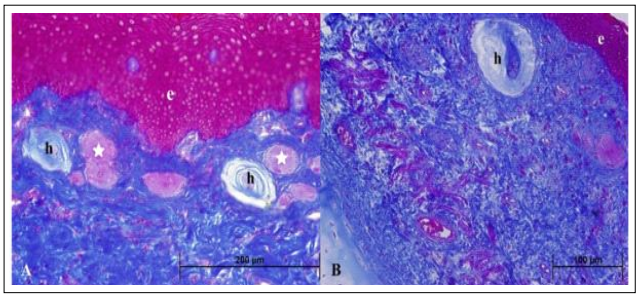


Fig 3: A. Section of the rostral conchae. Stratified squamous epithelium (e), Grandry's corpuscles (star). x20 **B.** Nonkeratinized stratified squamous epithelium (e), Herbst corpuscle (h), Grandry's corpuscles (star). Triple staining.

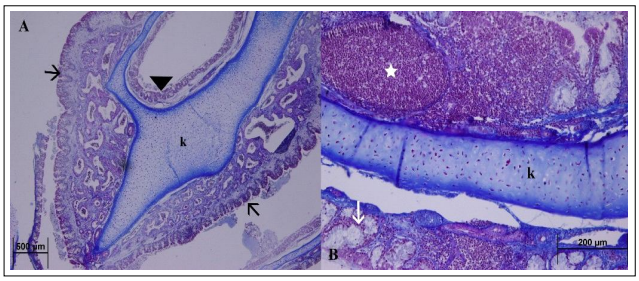


Fig 4: A. Spiral structure of middle conchae. A concave (arrowhead) and a convex (arrow) surface. **B.** Lymphoid follicles in the mucosa (star), intraepithelial alveolar glands (arrows), Hyaline cartilage (k). Triple staining.

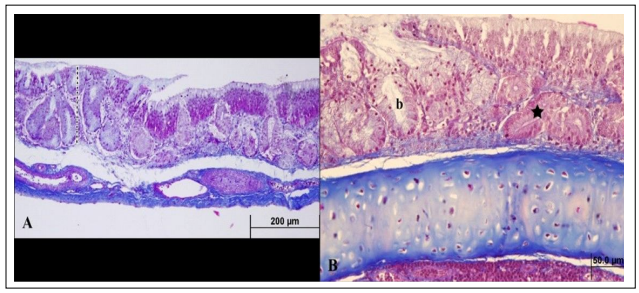


Fig 5: A. Transition between the middle and caudal conchae. Frontier between middle and caudal conchae (-). **B.** Mucous intraepithelial alveolar glands in the middle concha (star), serous Bowman's glands (b). Triple staining.

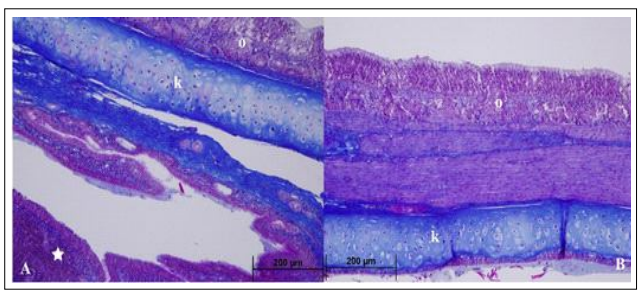


Fig 6: A. Longitudinal section of caudal concha. Olfactory epithelium (o), respiratory epithelium (star). **B.** Olfactory epithelium of caudal concha (o), Bowman gland (arrow), duct of Bowman gland (arrowhead), hyaline cartilage (k). Triple staining.

glands close to the lumen (Fig 7B). In the AB/PAS staining performed on the following section, it was seen that the PAS-AB material stained in blue, purple and pink tones, including both neutral and acidic mucins; this revealed that the glands secrete a mixed character (Fig 7C). Applying the AB/AF technique to successive sections of the same part resulted in the entire secretion staining blue, indicating that all acidic mucins were of the carboxylated type (Fig 7D).

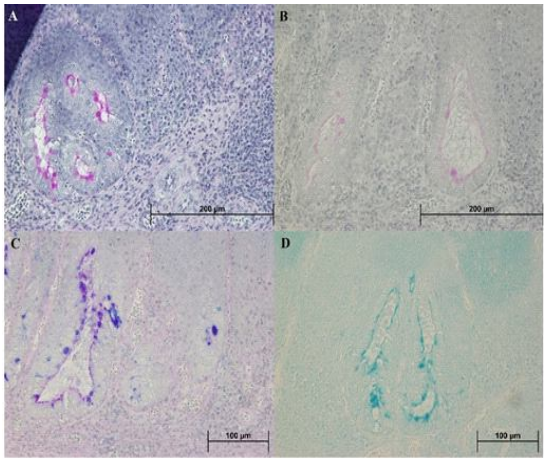
Middle concha section

In the staining applied to the middle concha section, it was determined that the histological structures and histochemical properties of the glands located in the helically folded mucosa differed depending on whether they were located on the concave or convex surface of the mucosa. While diffuse staining was observed in the secretory cells of the tubular and multi-layered glands located on the convex side, it was determined that only some cells were stained in the intraepithelial glands located as epithelial invaginations on the concave surface and therefore, not all cells contained mucin. In PAS staining, quite strong PAS positivity was detected in some of the cells forming the tubular glands, showing diffuse positivity on the convex surface and the glands on the concave side (Fig 8A). In PH/PAS staining, diffuse reactivity was seen especially in the glands in the outermost ring, while in the other rings, a significant positivity was observed only in the goblet-like cells located in the concave part (Fig 8B). It was noted that cells showing strong PH/PAS reactivity exhibited mixed character in AB/PAS staining (Fig 8C), while the cells giving the most intense AB(+) reaction in AB/AF staining were those showing the most intense AB (+) reaction (Fig 8D). In general, it was determined that the glands on the convex surface were mostly rich in carboxylic acidic mucins (Fig 8D), while the glands on the concave surface contained neutral mucin, except for the goblet-like cells that gave intense reactions in PH/PAS and AB/AF stainings (Fig 8B, D).

Caudal concha section

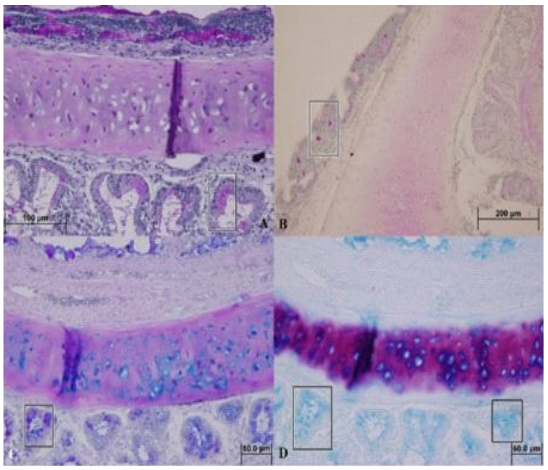
In PAS staining applied to the sections of the caudal concha, no mucin presence was detected in this mucosal section (Fig 9A). However, it was determined that the apical surface of the epithelial cells in the part covered with respiratory mucosa was covered with a secretory layer containing neutral and acidic mucin (Fig 9B). In sections of the middle-caudal turbinate transition zone, Bowman's glands, which did not show mucin content, were found in the lamina propria of the caudal turbinate mucosa continuing from the convex surface of the middle turbinate. The epithelium on the concave surface of the middle turbinate was observed to continue in a modified form towards the inner parts of the caudal turbinate. In this region, the intraepithelial alveolar glands within the respiratory epithelium disappeared and were replaced by a small number of goblet cells. Furthermore, the absence of the lamina propria layer in this area was noted (Fig 9C, D).

Many respiratory diseases are directly related to structural changes in the mucosa of the nasal septums. For example, hypertrophy of the mucosa leads to nasal obstruction, while atrophy causes the nasal mucosa to appear dry, bleeding and prone to crusting. Changes in the physical and chemical properties of nasal mucus affect its viscoelastic structure, paving the way for the development of respiratory diseases. Disruption of the respiratory epithelial physiology in the nasal turbinate can also lead to the development of rhinitis, rhinosinusitis and various lung diseases (Millas *et al*., 2009). Histochemical studies of



A. PAS staining **B.** PH-PAS staining. **C.** PAS-AB staining. **D.** AB(+) stained carboxylated acidic mucins. AF(+) Hyaline cartilage. AF/AB staining.

Fig 7: Histochemical staining of rostral concha.



A. There is a strong PAS reaction on the concave surface and a diffuse and weaker reaction on the convex surface glands (□). **B.** PH-PAS stained cells (□). **C.** Concave surface (□) and convex surface (arrow) AB and AB-PAS staining. **D.** In the conchae the strongest AB/AF reaction (□).

Fig 8: Histochemical reactions of tubular glands (□) and the intraepithelial alveolar glands (arrow) of middle concha, the most concentreted stained group of cells (□).

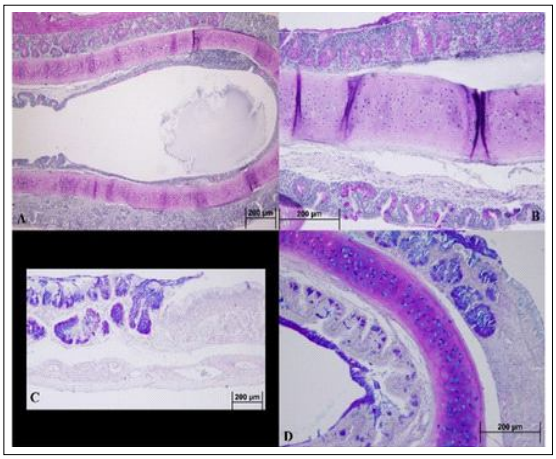


Fig 9: A. Lengthwise section of the caudal concha. PAS staining. **B.** The caudal concha. PAS staining. **C.** Transition between the middle and caudal conchae. AB/PAS staining technique. **D.** Passageway between the middle and caudal conchae. PAS/AB staining.

the nasal mucosa have shown that the secretions of goblet cells and glands, which produce mucus, an important component of the mucociliary clearance mechanism, generally contain neutral and acidic mucins. Furthermore, it has been shown that the character of the secretion can vary depending on different parts of the nasal turbinate, differences between species and disease states (Nogueira *et al*., 1976).

It has been reported that the morphological structure of the nasal turbinate differs among species; rodents and dogs have a more complex organization compared to primates and humans (Renne *et al*., 2007). Studies conducted on different bird species have also revealed various structural differences. For example, it is stated that the forest crow has rostral and caudal turbinate sections in the nasal cavity, but the caudal turbinate is not clearly distinguishable. In a study conducted on the Denizli rooster, it was stated that the nasal cavity shows a rostrally oriented pointed conical structure and is divided into two compartments, right and left, by a cartilaginous septum. It was reported that each nasal cavity consists of rostral, middle and caudal turbinate sections and that the middle turbinate constitutes the largest part among these. It was also stated that in the transverse section of the middle turbinate, the cartilaginous projection folds approximately 1,5 turns upon itself (Yokosuka *et al*., 2009). Reported that the rostral part of the nasal mucosa in chickens is covered with stratified squamous epithelium, the middle part with pseudostratified prismatic epithelium and the caudal part with olfactory epithelium (Watanabe *et al*., 2020). Research on mucus-secreting cells in the airways of cats and geese, stated that cats have numerous goblet cells and submucosal glands in the trachea; whereas geese have intraepithelial glands formed by the fusion of numerous goblet cells instead of submucosal glands (Jeffery, 1978). In a morphological study conducted on quail, it was stated that there are three concha segments and the widest part is the middle concha; it was emphasized that the concha projections make approximately one and a half turns of fold. It was also stated that the rostral concha has a “C”-shaped morphology. The findings of the presented study show that the duck is similar to quail, rooster and chicken in terms of being divided into three main regions in terms of concha segments; However, it reveals that the conchal projections only share similarities in terms of curvature shape with geese belonging to the same genus (Çevik-Demirkan *et al*., 2007).

Limited histological studies on birds report that in species with three turbinate segments, the nasal cavity, starting from the nostrils, has three turbinate segments: the rostral turbinate in the vestibulum is covered with stratified squamous epithelium, the middle turbinate with respiratory epithelium and the caudal turbinate with olfactory epithelium (Kang *et al*., 2014; Bang and Bang, 1969; Al-Ahmed and Sadoon, 2020). However, some literature sources (Geist, 2000) and studies (Dar *et al*., 2014) state that both the rostral and middle turbinate segments are covered with respiratory mucosa. Our study revealed that duck nasal turbinates consist of three separate turbinate segments. In this respect, although it shows similarities to other poultry species with three different epithelial types belonging to the three turbinate segments, it has been determined that the histological features, especially those of the middle turbinate, largely coincide with the findings reported in cats and geese (Jeffery, 1978). The respiratory system mucosa constitutes a region where direct contact occurs as a result of inhalation of air contaminated with microorganisms (Kang *et al*., 2013). The mucus in the mucosa of this system ensures the retention of foreign particles and microorganisms taken in by inhalation; then, thanks to ciliary activity, it mediates the removal of these structures from the environment (Ali and Pearson, 2007). In a study conducted on experimentally infected chickens, following the inoculation of the nasal mucosa with the Newcastle virus, it was determined that the number of infected cells in the middle turbinate segment reached its highest level within the first hour; and towards the fifth hour, the amount of infective cells decreased in parallel with the increase in mucus secretion. Based on these findings, it was concluded that increased nasal mucus secretion is effective in removing the virus (Bang and Foard, 1969; Zaki *et al*., 2025). In a study on mucus movement in the nasal turbinates of chickens, it was stated that the helical projections in the middle turbinate increase the surface area of contact between the inhaled air and the nasal mucosa; furthermore, the dense arterial and venous capillary network in the subepithelial region contributes to the humidification and warming of the air (Bang and Bang, 1969). The narrow lumen in the section where the projections are located in the nasal passage, along with the convoluted structure of these projections, which form

concave-convex surfaces, create turbulence in the airflow. As a result of this turbulence, it is reported that particles are trapped by mucus on the convex surface, then transported to the concave surface by mucus flow, where they accumulate and are transmitted to the pharynx *via* the lacrimal duct and sinuses (Bang and Foard, 1969). Thus, the inhaled air is filtered and brought to suitable physical conditions before reaching the lower respiratory tract (Hodges, 1974; Morawska, 2022). In the presented study, it was determined that the conchal projections in the middle concha region of ducks are significantly convoluted, forming two full and one half ring and that this structure significantly narrows the nasal lumen. These morphological features are thought to indicate the presence of an efficient mucociliary cleaning mechanism in ducks.

In poultry, the nasal mucosa is reported to contain aggregated lymphoid tissue clusters called NALT (Nasal Associated Lymphoid Tissue) because it is the region where the first contact with the air occurs and constitutes the main entry point for various pathogens. NALT is considered the primary induction site in both natural infection and mucosal vaccination settings. In poultry, vaccination methods such as nasal drops, beak dipping and sprays are frequently performed via the nasal mucosa (Kang, 2013). Mucosal vaccination is considered a promising alternative to parenteral vaccines due to its non-invasive nature and its ability to generate strong local and systemic immune responses, particularly in MALT (Mucosa Associated Lymphoid Tissue). The nasal cavity; Due to its rich vascular structure, large surface area and NALT content, the nasal mucosal region stands out as an important area that increases the effectiveness of vaccines in mucosal applications (Torrieri-Dramard, 2011). It is stated that nasal mucosal barriers and mucociliary transport mechanisms are effective in antigen recognition and activation of intranasal immunization in poultry species; therefore, poultry have a certain nasal absorption capacity (Kang, 2013). In chickens, numerous glandular structures formed by cup cells and diffuse lymphoid tissue defined as NALT are located in the subepithelial area of the middle concha; it is reported that the middle and caudal nasal regions are the main areas where nasal immunization takes place (Hodges, 1974). In the presented study, solitary lymph follicles were found in the rostral-middle and middle-caudal concha transition zones in ducks and aggregate lymph follicles were observed at the tip of the deepest helical fold of the middle concha. In birds, especially waterfowl such as ducks and geese, it is reported that there are two types of mechanoreceptors sensitive to pressure and vibration: Herbst and Grandry corpuscles. Grandry corpuscles are mostly located in the beak region, while Herbst corpuscles are found in the beak and oral cavity as well as in different parts of the body (Gottschaldt and Lausmann, 1974). This study demonstrates that these receptors are also subepithelially located at the entrance of the rostral concha of the duck.

The epithelium of the respiratory system and the mucous membrane covering it actively protect the mucosa against developing infections and tissue damage. Mucus and mucociliary transport, which are important components of non-specific defense, especially in the air-conducting section, are of great importance for two main reasons: (1) the removal of harmful substances and particles as a mechanical “escalator” system and (2) contributing to immune defense through various mediators it contains. Various dyes, saccharin and particle tests are used to evaluate the speed and efficiency of mucociliary transport (Trindade *et al*., 2007). Thanks to the presence of mucins, nasal mucus can bind to substances such as pathogens and drugs and also has a slightly acidic pH value in the range of approximately 5.5-6.5, which helps prevent infections (Beule, 2010). It is reported that nasal mucus is mainly secreted by mucous and serous glands and epithelial goblet cells located in the lamina propria. Studies on the histochemical properties of mucus in the nasal mucosa of poultry are limited. It has been reported that the mucous glands and goblet cells covering the respiratory mucosa in chickens show positive reactions in PAS and AB/Safranin O staining (Pal and Bharadwaj, 1970). In another study conducted on chickens, the AB (pH 1)/PAS technique was applied to distinguish between neutral and sulfated acid mucins; the results showed that Bowman’s glands showed an AB(+) reaction, the neck portions of the glands and goblet cells in the respiratory region stained PAS(+) and the body portions of the glands exhibited a mixed character containing both acidic and neutral mucins in a purple color (Bang and Bang, 1969). In the presented study, it was determined that the majority of the mucus-containing glands in the rostral turbinate exhibited a mixed character containing neutral and acidic mucins, while the acidic mucin content was more pronounced in the glands located in the convex region of the middle turbinate. The presence of sulfated and carboxylated types of acid mucins was evaluated by the AF/AB staining method; no AF(+) mucin was found outside the cartilage tissue matrix. This finding indicates that the acid mucins found in duck nasal turbinates belong to the carboxylated mucin, *i.e*., sialomucin group.

It was determined that glands containing only neutral mucin and periodate-reactive type mucin, as well as goblet cells, are mostly located in glands situated on the mucosa of the concave surface of the middle turbinate circural. When the obtained histochemical findings are evaluated in line with study on mucus movement in chickens (Bang and Bang, 1969), it is thought that airborne droplets and pathogens reaching the respiratory mucosa in ducks first encounter the secretion of convex surface glands containing sialomucin, then this mucus is transported to the concave surface, where its acidity and potential toxicity are reduced through neutral mucins and after interaction with aggregate lymph follicles located on the spiral concave surface, it is transmitted to the pharynx in a controlled manner. Therefore, when evaluated both histologically and

histochemically, it is understood that the convex and concave surfaces of the middle turbinate spiral play an important functional role.

CONCLUSION

In conclusion, the findings obtained determine that the rostral and caudal sections of the duck nasal turbinates; The study shows that the nasal turbinate primarily serves sensory functions due to the presence of mechanoreceptors and olfactory epithelium, while the middle turbinate, with its distinctly convoluted turbinate projections and the high concentration of sialomucins and aggregated lymph follicles involved in pathogen adhesion, possesses an effective intranasal immunization mechanism in terms of histomorphology and histochemical analysis. Considering the form-function relationship, these features may explain the resistance that ducks, belonging to the "waterfowl" group, have developed to respiratory diseases, depending on their habitat conditions. The elucidation of the histological and histochemical structure of the nasal turbinates in healthy ducks will also provide a scientific basis for the comparative evaluation of changes in the nasal mucosa in future studies on intranasal immunization or other experimental applications.

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Disclaimers

The views and conclusions expressed in this article are solely those of the author and do not necessarily represent the views of their affiliated institutions. The author are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

This study used material from a slaughterhouse and the tissue samples were not subject to ethical committee approval in accordance with the Regulation on the Working Procedures and Principles of Animal Experimentation Ethics Committees of the Ministry of Forestry and Water Affairs of the Republic of Turkey (dated 15 February 2014, No. 28914).

Conflict of interest

The author declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish or preparation of the manuscript.

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