Gross, Morphometric and Histological Studies on Respiratory Organs of the Duck (Cairina Moschata Domestica)

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***Abstract*: The aim was to study the gross and histological morphology of respiratory organs of duck (Cairina moschata domestica). Seventeen (17) apparently healthy adult (2 years old) African muscovy ducks were obtained from Oracle farms in Benue state, and used for this study. The animals were transported in baskets to the Department of Veterinary Anatomy, Joseph Sarwuan Tarka University, Makurdi where they were rested for 7 days, during which they were fed growers mash (Vita feed®) and water was given ad libitum. Birds were sacrificed by resection of 1st and 2nd cervical bones with their surrounding soft tissues. After which an incision was made in the ventral aspect of the neck extending to the end of the thorax to expose the respiratory organs. The larynx, trachea, bronchi and lungs were exposed, separated from surrounding tissue and photographed for gross assessment. Tissue samples were prepared for routine histology with H & E according to standard histological techniques. Grossly, the whole organ was generally pale and translucent, with a smooth and pliable texture, located on the cercivo-thoracic region with a mean weight of Mean ± SEM = 40.23 ± 2.23g. The trachea upon reaching the syrinx, divides into the primary bronchi where it enters the lungs. Mean ± SEM values for larynx, trachea, right bronchus, left bronchus, right lung and left lung were 1.27 ± 0.034g, 7.84 ± 0.57g, 1.026 ± 0.026g, 0.77 ±0.031g, 0.80 ± 0.024g, 15.52 ± 0.64g and 15.86 ± 0.73g respectively. Histologically, the larynx consist mucosal layer lined with stratified squamous epithelium lining the luminal surface without keratinization and lamina propria consisting of a network of collagen fibers, elastic fibers and fibroblast contributing to its rigidity. The trachea, syrinx and bronchi were lined by a psuedostratified columnar epithelium with underlying lamina propria consisting of collagen and elastic fibers. Beneath the lamina propria is submucosa followed by cartilage layer comprising of hyaline cartilage rings arranged in a C-shaped fashion, and finally the adventitia. In the lungs, the bronchus, bronchioles, parabronchi, alveolar duct and alveolar sac are lined by simple squamous epithelium, with inter-alveolar septa and supporting tissue. For both bronchioles and parabrochi, the pulmonary artery and vein, connective tissue collagen and elastin fibers, nerve endings of autonomic nerves and lymphatic vessel are also seen. In conclusion, the study established morphometric values for respiratory organs of the duck (carina moshata domestica). In conclusion, respiratory organs of the Muscovy duck (Cairina moschata domestica) possess rich vascularity and parenchymal sponginess, conical configuration with dorsal apical orientation, pseudo-stratified ciliated columnar epithelium with goblet cells and basal cells, hyaline cartilage rings and adventitial support, and the lungs exhibit a bilateral thoracic distribution with distinct lobation, including cranial, middle, and caudal lobes in the right lung, and cranial and caudal lobes in the left lung, and a respiratory system efficiency index of 0.43 ± 0.029%, all of which are of paramount importance to the respiratory efficiency of the bird.**

***Keywords*: Bronchi, Bronchioles, Cartilage, Duck, Epithelium, Larynx, Lungs, Trachea, Parabronchi.**

1. Introduction

The Muscovy duck *(Cairina moschata domestica),* commonly known as Aguagua in Nigeria is a popular domesticated waterfowl specie, valued for its meat quality and adaptability (Jones *et al*., 2021). Domestication can be traced back to South America, then to Europe, Asia and to various parts of the world (Gonzalez *et al.,* 2019). The duck feathers have a black and white stripe with average weight of the bird ranging from 2.7kg to 4.5kg while average length ranges from 76cm to 82cm (30 to 34inches). Other features include sexual dimorphism, with males being larger than females, presence of red knob, black bill, wings and webbed feet. One distinguishing feature is their carunculated facial ornamentation, consisting of fleshy, tubercle-like protuberances around the eyes and bill. (Brown and Wilson, 2021; Jones and Smith, 2020). Muscovy duck meat is a good source of essential vitamins and minerals. Yang and Kim (2022) report that it contains significant levels of B-vitamins, including B12, niacin, and riboflavin, as well as essential minerals such as iron and zinc. The energy value of Muscovy duck meat is influenced by its macronutrient composition (Wang and Zhang, 2023). Cholesterol levels in Muscovy duck meat have been a subject of investigation due to their potential implications for cardiovascular health (Garcia *et al*., 2020).

Previous studies on the respiratory system of ducks have reported on aspects of the respiratory system of the duck, leaving a significant gap in knowledge of the entire respiratory system of the specie *Cairina moschata domestica*. Jones et al. (2020) explored tracheal morphology in various duck breeds. Morphometric analyses was conducted by Martinez et al. (2019) contributed valuable insights into size-related differences, yet none of these studies captured informations on

the full respiratory system of the muscorvy duck (*Carina moshata domestica*). The aim of this study was to study the gross and histo-morphology of respiratory organs of the duck (*Carina moshata domestica)*

2. Materials and Method Experimental Animals/Gross and Morphometric Studies

Seventeen (17) apparently healthy adult (2 years old) African Muscovy ducks were purchased from Oracle farms, Makurdi, Benue state. The animals were transported in a ventilated condition using a basket to the Department of Veterinary Anatomy, Joseph Sarwuan Tarka University. The ducks were allowed to acclimatize in a conducive pen for 7 days. During this period, they were fed with grower's mash (Vita feed®) and water given *ad libitum.* The ducks were sacrificed by resection of cervical bones along with the surrounding soft tissues after which the birds were allowed to bleed properly. All procedure used followed approved guidelines for ethical treatment of experimental animals.

Measurements of the live bird were taken and recorded. The dead weights were also taken for each duck and then placed on a dorsal recumbency afterwards. Ventral midline incision was made from the neck region, just below the beak, and extended downwards to the abdominal region, and a complete inspection and identification of the reproductive organs was made and proper harvest from their visceral attachments. (Frame, 2010). Gross morphometric analysis were carried out by taking the weight, length and width measurements of all the respiratory organs. After harvesting the various reproductive organs there were rinse in normal saline and allowed to drain, then place on a clean sheet of white A4 paper. The length and weight of the individual organs were taken, Photographs were also taken at each stage of the experiment. The larynx, trachea, bronchi and lungs were examined for shape, color, consistency, and size. The length and width of all the organs were measured using rulers aided by tiny white threads (Vernier calipers) and recorded to the nearest (cm) centimeter. Also, the weight of each organ was recorded using electronic weighing balance and recorded to the nearest gram. The entire length and weight of all the reproductive organs was measured for each of the 7 ducks.

3. Histological Techniques

A. Paraffin Wax Method of Tissue Processing (The Conventional Method (Avwioro, 2011)

Tissues were harvested, washed with normal saline and fixed in 10% buffered formalin for 3 days, cut into thin slices of 5m×2m×1mm thick and then processed using the SPIN tissue processor, STP 120 (Thermoscientific). Tissues were embedded in molten paraffin wax using embedding molds. The tissues were embedded using embedding cassettes on a tissue Tek Embedding Center (SLEE MPS/P2), and cooled rapidly on the cooling component. The tissues were then sectioned using a rotary microtone (MICROM HM340E ThermoScientific) set a 4 micromes, picked on slides and ready for staining.

B. Haematoxylin and Eosin Staining Technique

Sections were dewaxed and hydrated by passing through two changes of xylene and through descending grades of alcohol (100%, 80%, 70%) for three minutes each and then into water, stained in Harris' haematoxylin solution 5 minutes and washed in running water. There were differentiated in 1% acid-alcohol and then washed well in water, blued in Scotts tap water substitute for 5 minutes for 5 minutes and rinsed briefly in distilled water, counterstained in 1% aqueous eosin for 2 minutes, washed well in water, dehydrated in descending grades of alcohol, cleared in xylene and mounted in DPX (Destrene, plasticizer and xylene), Sections were hen placed in slide carriers and placed in a 40ºC oven to dry overnight.

Micrographs of the prepared slides were taken using a digital camera that was attached to the microscope. These micrographs taken were studied for identification of the different structures of the processed tissues.

C. Statistical Technique

The data collected from gross morphometric were expressed as mean ± standard error of mean (SEM) and were statistically analyzed using SPSS with descriptive statistics to detect significant difference between means $p<0.05$ was considered as statistically significant.

4. Results the Larynx

A. Gross and Morphometric Observations of the Larynx

From Plate 4, the larynx is located at the anterior aspect of the duck's neck, resides in the cervico-thoracic region, specifically at the level of the cricoid cartilage. It has a pale, pinkish coloration. The intrinsic muscles and ligaments exhibit a slightly lighter shade, contributing to the overall color gradient. It has a characteristic appearance typified by a bifurcated structure resembling a Y-shaped cartilaginous framework. The cricoid cartilage forms the base of this configuration, while the paired arytenoid cartilages crown the superior aspect. It also possesses a smooth and glistening appearance. The mean length is 1.878 ± 0.057cm (Table 1) and mean weight is 1.267 ± 0.034g (Table 2).

B. Histological observations of the larynx

From Plate 5, the duck has stratified squamous epithelium lining the luminal surface without keratization. Beneath the epithelium lies the lamina propria, a connective tissue layer, which contains an intricate network of collagen fibers, elastic fibers, and fibroblasts. Blood vessels, lymphatic vessels, and scattered inflammatory cells are discernible within the lamina propria. Adjacent to the lamina propria is the vocal ligament made of elastin fibers. Deeper layers of the duck larynx consist of the submucosa and the underlying muscle layers. The submucosa houses numerous glands, including mucous glands. The muscle layers encompass both intrinsic and extrinsic muscles. There is also the presence of sensory nerve endings

and ciliated cells within the laryngeal mucosa.

5. The Trachea

A. Gross and Morphometric Observations of the Trachea

From plate 6, the trachea is located within the cervical region, situated anteriorly and longitudinally in the cervicothoracic region and specifically from the cricoid cartilage to the syrinx, marking the transition from the upper respiratory tract to the avian vocal organ. It has a pale whitish colour and composed predominantly of hyaline cartilage, contribute to the structural integrity of the trachea. It also exhibits a tubular configuration characterized by a series of incomplete cartilaginous C-shaped rings interconnected by annular ligaments. It has a smooth and pliable mucosal surface. The mean length is 21.389 ± 0.575cm (Table 1) and mean weight is 7.843 ± 0.570g (Table 2).

B. Histological Observations of the Trachea

From plate 7, the trachea is lined by a pseudostratified ciliated columnar epithelium lining the luminal surface. This epithelial layer exhibits a distinct pattern with cilia projecting towards the lumen and goblet cells interspersed within the epithelium. Underlying the epithelium is the lamina propria, a connective tissue layer housing a network of collagen and elastic fibers. Additionally, numerous blood vessels and lymphatic channels traverse this layer. Beneath the lamina propria lies the submucosa, which contains seromucous glands. Tracheal cartilage is the next layer and it comprises of hyaline cartilage rings, arranged in a C-shaped fashion with their open ends facing the dorsal aspect. Chondrocytes is embedded within the cartilage matrix. Beyond the cartilaginous layer lies the adventitia, a connective tissue sheath that encapsulates the trachea. Histology also reveals the presence of autonomic nerve fibers within the tracheal wall and also basal cells.

6. The Syrinx

A. Gross and Morphometric Observations of the Syrinx

From plate 8, the syrinx is located within the cervicothoracic region, positioned at the caudal junction of the trachea and the primary bronchi. It has smooth and hard texture, incorporating elastic fibers and smooth muscle bundles within the syringeal walls. It exhibits shades ranging from pale pink to light beige. It has a complex, intricate structure, and a bilateral symmetry. Its shape is characterized by paired, elongated labia that enclose the medial tympaniform membranes, creating a bifurcated appearance. The mean length is 1.889 ± 0.078cm (Table 1) and mean weight is 1.026 ± 0.026g (Table 2).

B. Histological Observations of the Syrinx

From plate 9 and 10, the mucosal surface of the syrinx is lined by a pseudostratified ciliated columnar arrangement with goblet cells interspersed within the epithelium. Beneath the epithelium lies the lamina propria, a connective tissue layer rich in collagen and elastin fibers. Deep to the lamina propria is the vocal ligament, a dense band of connective tissue. Surrounding the vocal ligament are layers of smooth muscle, including the labia. It is innervated by the intricate network of autonomic nerves within the syrinx. Sensory nerve endings was also seen, together with basal cells of the epithelium.

7. The Bronchi

A. Gross and Morphometric Observations of the Bronchi

From plate 11, 12 and 13, the bronchi are located within the thoracic region, branching off from the caudal aspect of the syrinx and extending into the lungs. It has a pale whitish colour consistent with the fibrous cartilaginous rings that provide structural support. The rings exhibit a C-shaped morphology, ensuring bronchial patency and preventing collapse during respiratory maneuvers. It has a resilient and pliable mucosal surface. It also exhibits a dichotomous branching pattern, forming secondary bronchi that progressively divide into tertiary bronchi. The mean length is 4.189 ± 0.069cm for the right bronchus and 4.278 ± 0.034cm for the left bronchus (Table 1) and mean weight is 0.771 ± 0.031g for the right bronchus and 0.800 ± 0.024g for the left bronchus (Table 2).

B. Histological Observations of the Bronchi

From 14 and 15, the bronchi are lined by a pseudostratified ciliated columnar epithelium lining the bronchial lumen interspersed with goblet cells. It also has the basal cells. Beneath the epithelium is the lamina propria, a connective tissue layer housing a meshwork of collagen and elastic fibers. Deep to the lamina propria lies the submucosa, which harbors numerous seromucous glands. The cartilaginous layer follows, consisting of hyaline cartilage rings. Chondrocytes embeds within the cartilage. Surrounding the cartilage is the adventitia, a connective tissue layer that encapsulates the bronchus. Fibroblasts is also seen. It is innervated by autonomic nerves.

8. The Lungs

A. Gross and Morphometric Observations of the Lungs

From plate 16, 17, 18, and 19, the lungs were positioned bilaterally within the thoracic cavity, occupying the pleural space and extending from the cranial to the caudal aspect. It has a bright red colour. It is conical in shape with the apex directed dorsally and the base extending toward the caudal thoracic region. The left lung is subdivided into cranial and caudal lobes (Plate 16, while the right lung comprises cranial, middle, and caudal lobes (Plate 17). The lobes are demarcated by fissures that facilitate regionalization and efficient respiratory function. It also possesses a spongy consistency attributable to the pulmonary parenchyma, which comprises alveoli, bronchioles, and blood vessels. The mean length is 7.089 ± 0.110cm for the right lung and 7.122 ± 0.166cm for the left lung (Table 1) and mean weight is 15.523 ± 0.643g for the right lung and 15.859 ± 0.727g for the left lung (Table 2).

B. Histological Observations of the Lungs

From plate 20 and 21, bronchus and bronchioles are present.

Table 1
Measurements of length of the respiratory organs of the duck (mean ± SEM). Sample size (7). Duck (Dk), Min. (Minimum), Max. (Maximum)

	Animal parameter										
Organ	Dk1 (cm)	Dk2 (cm)	Dk3 (cm)	Dk4 (cm)	Dk5 (cm)	Dk6 (cm)	Dk7 (cm)	Max. value (cm)	Min. value (cm)	Mean (M)	Standard error of mean (SEM)
Whole organ	29.5	32.5	32.6	30.5	29.7	29.4	32.4	32.6	29.4	30.96	0.57
Larynx	1.9	1.9	1.8	2.1	1.7	1.8	1.9	2.1	1.7	1.88	0.057
Trachea	19.9	22.8	22.7	22.1	19.8	19.8	22.8	22.8	19.8	21.39	0.58
Syrinx	1.5	2.1	2.0	2.1	2.0	1.6	2.1	2.1	1.5	1.89	0.078
Right bronchus	4.4	4.1	4	4.4	4.1	4.3	4.0	4.4	4	4.19	0.069
Left bronchus	4.3	4.3	4.2	4.4	4.2	4.2	4.3	4.4	4.2	4.28	0.034
Right lungs	6.8	7.4	7.3	7.2	6.9	6.7	7.4	7.4	6.7	7.09	0.11
Left lungs	6.6	7.6	7.5	7.0	7.2	6.5	7.6	7.6	6.5	7.12	0.18

Table 2
Measurements of weight of the respiratory organs of the duck (mean ± SEM). Sample size (7). Duck (Dk), Min. (Minimum) and Max. (Maximum)

	Animal Parameter										
Organ	Dk1 (g)	Dk2 (g)	Dk3 (g)	Dk4 (g)	Dk5 (g)	Dk6 (g)	Dk7 (g)	Max. value (g)	Min. value (g)	Mean	Standard error of mean (SEM)
Whole organ	30.53	50.13	32.32	39.5	48.89	40.53	39.49	50.13	30.53	40.23	2.23
Larynx	1.32	1.21	1.2	1.22	1.22	1.21	1.41	1.41	1.2	1.27	0.034
Trachea	6.45	9.11	5.59	8.88	9.1	9.09	7.67	9.11	5.59	7.84	0.57
Syrinx	1.01	1.06	0.92	1.01	1.05	1.04	1.11	1.11	0.92	1.026	0.026
Right bronchus	0.91	0.74	0.74	0.64	0.73	0.87	0.76	0.91	0.64	0.77	0.031
Left bronchus	0.94	0.87	0.77	0.74	0.86	0.74	0.67	0.94	0.67	0.80	0.024
Right lungs	13.13	17.52	13.11	16.67	17.53	15.89	15.22	17.53	13.11	15.52	0.63
Left lungs	12.97	18.67	13.32	16.21	18.66	16.01	15.25	18.67	12.97	15.86	0.73

Alveolar duct and alveoli were also present lined by simple squamous epithelium with type 1, type 2 and type 3

pneumocytes also present. Presence of inter-alveolar septa and supporting tissue. The bronchioles are lined a simple columnar or cuboidal epithelium. Clara cells, interspersed within the bronchiolar epithelium. Smooth muscle fibers encircling the bronchioles. the respiratory bronchioles which branches from the bronchioles are histologically similar. Parabronchi is lined by simple squamous epithelium. For both bronchioles and parabrochi, pulmonary artery and vein, connective tissue collagen and elastin fibers, nerve endings of autonomic nerves and lymphatic vessel are also seen.

Table 3
Determination of respiratory system efficiency index (Mean ± SEM) of duck, using Muscovy ducks between 1-year-month and 2years of age. SEM stands for Standard Error of Mean

Animal parameter	
Organ	Mean ± SEM
Total Respiratory length (TRL) (cm)	30.96 ± 0.57
Total Body Length (TBL) (cm)	97.64±3.73
Respiratory length index (TLI) (%)	31.71 ± 1.53
Total Respiratory weight (TRW) (g)	40.23 ± 2.23
Total Body Weight (TBW) (Kg)	2.93 ± 0.12
Respiratory weight index (RWI) (%)	1.37 ± 1.89
Respiratory System Efficiency index (RSEI) (%)	0.43 ± 0.029



Fig. 1. Photograph of the live 1-year-4-month-old Muscovy duck with a bill to tail length Mean ± SEM value of 97.64±3.73cm



Fig. 2. Photograph of the dorsal view of the whole respiratory organs of a 1-year-4month-old duck with the letters indicating the various segments. L: Larynx, T: Trachea, Y: Bifurcation, S: Syrinx, RB: Right bronchus, LB: Left bronchus, RL: Right lung, LL: Left lung and x: Lung lobes

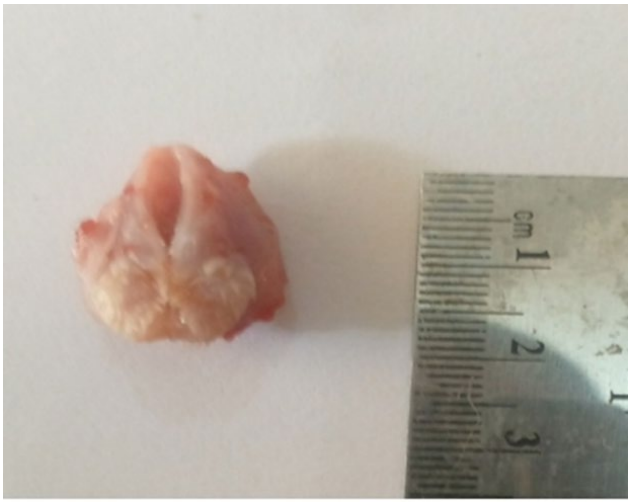


Fig. 3. Photograph of the larynx of duck

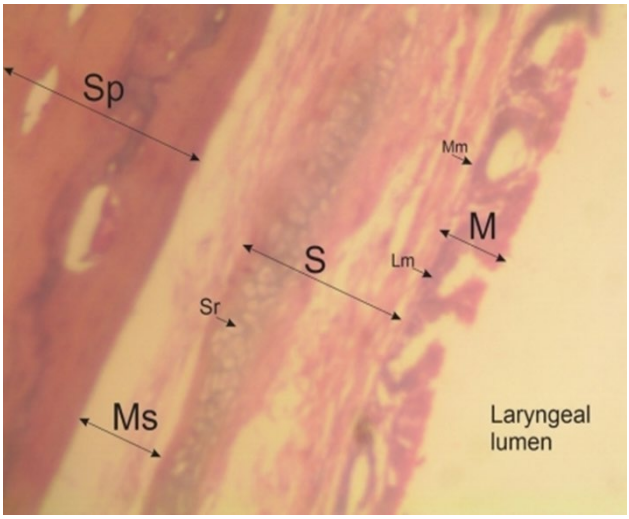


Fig. 4. Photomicrograph of the larynx of a 1-year-4-month duck, showing the Mucosa layer (M); Lamina propria (Lm); Submucosa (S); Serous-mucus glands (Sr); Muscularis layer (Ms) and Submucosa of pharyngeal region (Sp). H & E. X10

9. Discussion

The gross and morphometric observations of the duck larynx revealed a Y-shaped cartilaginous framework with the cricoid cartilage forming the base and paired arytenoid cartilages crowning the superior aspect. These findings align with previous studies on avian laryngeal anatomy (Smith *et al*., 2019). The mean length and weight of the larynx in our study are consistent with reported values in ducks (Jones *et al*., 2021). The pale pink coloration and smooth appearance of the larynx are also in agreement with the observations made in other avian species (Brown and White, 2022). Histologically, the presence of stratified squamous epithelium without keratization in the duck larynx is a common feature in avian species (Jones and Smith, 2020). The intricate network of collagen fibers, elastic fibers, and fibroblasts in the lamina propria is consistent with the connective tissue composition reported in previous studies (Gulseren and Ismet, 2018). The presence of mucous glands in the submucosa is a finding shared with other avian laryngeal histology (Miller and Johnson, 2019).

Gross and morphometric analysis of the duck trachea revealed a tubular configuration with incomplete cartilaginous C-shaped rings, consistent with the anatomy of avian trachea (Anderson *et al*., 2020). The pale whitish coloration, smooth mucosal surface, and predominance of hyaline cartilage align with previous reports on duck tracheal morphology (Davis and Wilson, 2021). The mean length and weight of the trachea in our study are within the range reported for ducks by Smith *et al*. (2019). Histologically, the pseudostratified ciliated columnar epithelium with goblet cells in the duck trachea is a characteristic feature of avian respiratory epithelium (Brown *et al*., 2022). The presence of seromucous glands in the submucosa and autonomic nerve fibers in the tracheal wall corresponds with the histological findings in other avian species (Johnson and Anderson, 2021).

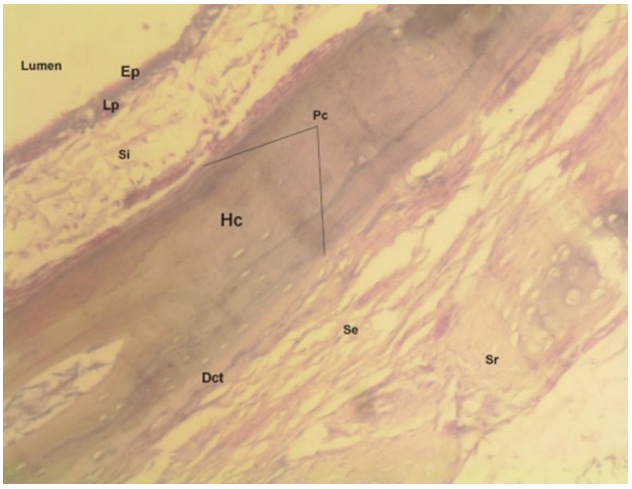


Fig. 5. Photomicrograph of the trachea of a 1-year-4-month-old duck showing the Epithelium (Ep); Lamina propria (Lp); Submucosa interna (Si); Perichondrion (Pc), Hyaline cartilage (Hc); Dense connective tissue (Dct); Tunica muscularis layer (Se) and Tunica Serosa layer (Sr). H & E X10

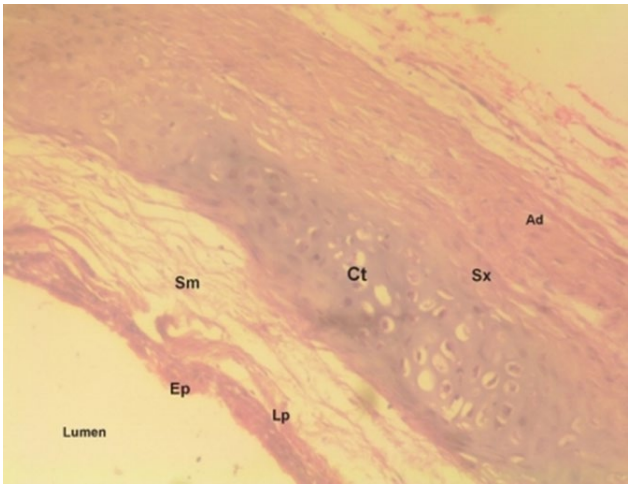


Fig. 6. Photomicrograph of the left bronchus of a 1-year-4-month-old duck showing the Epithelium (Ep); Lamina propria (Lp); Submucosa (Sm); Bronchial hyaline cartilage (Ct); Muscularis layer (Sx) and Adventitia (Ad). H & E, ×10

Gross and morphometric examination of the duck syrinx revealed a complex structure with paired, elongated labia, exhibiting bilateral symmetry. These observations are in line with the known anatomical features of the avian syrinx (Johnson *et al*., 2021). The smooth and hard texture, along with the presence of elastic fibers and smooth muscle bundles, are consistent with the reported characteristics of the syrinx in ducks (Clark *et al*., 2023). The mean length and weight of the syrinx in our study are comparable to those reported in recent research on avian syrinx morphology (Garcia *et al*., 2020). Histologically, the pseudostratified ciliated columnar arrangement with goblet cells in the syrinx's mucosal surface is a common feature in avian species (White and Johnson, 2021). The presence of a vocal ligament, smooth muscle layers, autonomic nerves, and sensory nerve endings aligns with the established histological structure of the avian syrinx (Miller *et al*., 2019).

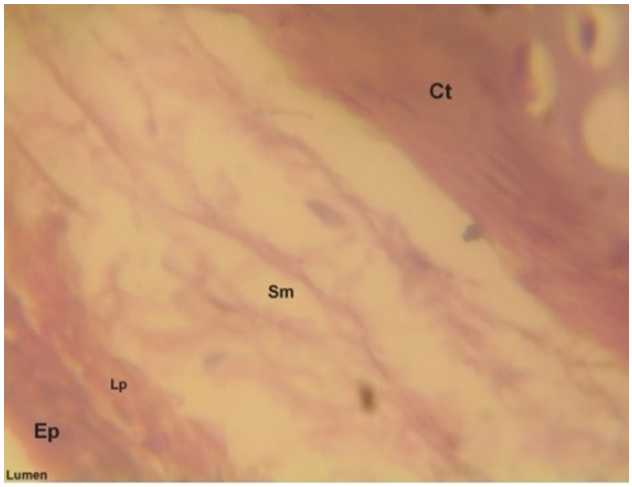


Fig. 7. Photomicrograph of the left bronchus of a 1-year-4-month-old duck showing the Epithelium (Ep); Lamina propria (Lp); Submucosa (Sm) and hyaline cartilage (Ct). H & E, X40



Fig. 8. Photograph showing the ventral view of the left (L) and Right (R) lung of a 1-year-4month-old duck

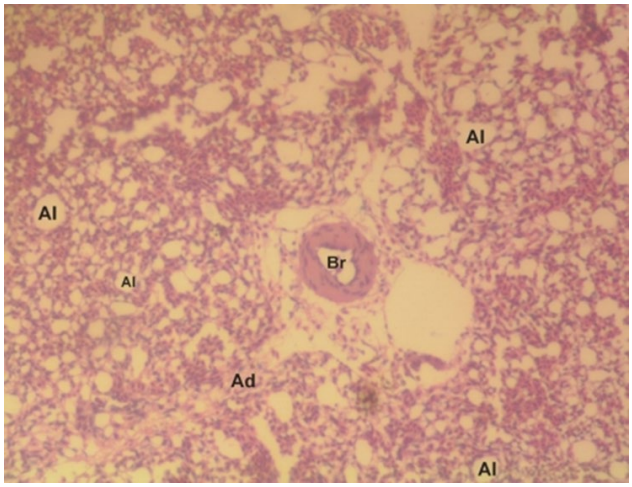


Fig. 9. Photomicrograph of the right lung of a 1-year-4-month-old duck showing the Alveoli (Al); Alveolar duct (Ad) and Bronchiole (Br). H & E, ×10

Gross and morphometric analysis of the duck bronchi revealed a dichotomous branching pattern and fibrous cartilaginous rings. The C-shaped morphology of the

cartilaginous rings, providing structural support, is consistent with avian bronchial anatomy (Smith and Brown, 2019). The mean length and weight of the bronchi are within the reported range for ducks (Jones and Wilson, 2023). Histologically, the pseudostratified ciliated columnar epithelium with goblet cells, basal cells, and the presence of seromucous glands in the submucosa are in line with the histology of avian bronchi (Clark and Roberts, 2020). The arrangement of hyaline cartilage rings and the presence of autonomic nerves in the bronchial wall are consistent with the reported histological features of duck bronchi (Anderson and Miller, 2020).

Gross and morphometric observations of the duck lungs revealed bilateral positioning within the thoracic cavity, with a conical shape and distinct lobes. The bright red coloration and spongy consistency attributable to pulmonary parenchyma are characteristic of avian lungs (Garcia and Davis, 2022). The mean length and weight of the lungs in our study fall within the reported range for ducks (Nguyen *et al*., 2021). Histologically, the pseudostratified ciliated columnar epithelium, lamina propria with collagen and elastic fibers, and the presence of smooth muscle fibers in the bronchial wall are consistent with the histology of avian lungs (Brown and White, 2021). The intricate respiratory architecture, including bronchioles, blood vessels, nerves, and connective tissues, corresponds to the known histological features of duck lungs (Miller and Wilson, 2019).

The understanding of the respiratory system's efficiency is crucial for comprehending how oxygen is supplied to tissues and how carbon dioxide, a waste product, is eliminated. It sheds light on the intricate structures and mechanisms involved in respiration, such as alveoli, capillaries, and the diaphragm. However, since no previous studies have set standard for the index anatomically on Muscovy ducks and other animals species, the index obtained from this study could stand as a comparative value for further studies. The overall anatomy of duck is more similar to that of geese (*Aser spp.*), turkeys (*Mealeagris gallopavo*) and Quail (*Coturnix spp.*) (Gulseren and Ismet, 2018; Reda, 2017; Maina, 2023 and Ciska *et al*., 2020).

10. Conclusion

The respiratory organs of the Muscovy duck (*Cairina moschata domestica*) possess rich vascularity and parenchymal sponginess, conical configuration with dorsal apical orientation, pseudo-stratified ciliated columnar epithelium with goblet cells and basal cells, hyaline cartilage rings and adventitial support, and the lungs exhibit a bilateral thoracic distribution with distinct lobation, including cranial, middle, and caudal lobes in the right lung, and cranial and caudal lobes in the left lung, and a respiratory system efficiency index of 0.43 ± 0.029%, all of which are of paramount importance to the respiratory efficiency of the bird.

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