Anatomical and Histological Study of the Female Reproductive System (*Columba oenas*) during the Egg-laying Period

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10.18805/ajdfr.DRF-578

ABSTRACT

Background: In this study, the female reproductive system of *Columba oenas* was examined during the egg laying stage, focusing on its general structure and microscopic characteristics.

Methods: Obsessive monitoring operations were performed, as well as different parts of the egg canal, which include infundibulum, magnum, isthmus, uterus and vagina.

Result: These parts showed clear anatomical differences, each with special textile features that seem to play distinctive roles related to the growth and movement of eggs. In magnum it was found that the bulk contains clear mucous folds and many secretory glands. The isthmus had a star-shaped lumen and was lined with a false cylindrical epithelium. In the uterus, branching tube glands, rich in multiple mucous sugars are observed, which are likely to contribute to the process of cortex formation. The vaginal area showed longitudinal folds consisting of cylindrical epithelial fabric. These changes combined indicate that the reproductive system adapts structurally while laying eggs to support the needs and laying eggs.

Key words: Al-aseel dove, Anatomy, Columba stock dove, Egg channel, Egg laying, Tissue science.

INTRODUCTION

Birds represent a significant group of vertebrates that have garnered considerable attention from researchers due to their distinctive centralized morphological and physiological traits (Williams, 2012; Yaseen *et al.,* 2025; M Obaid *et al.,* 2025). Understanding the avian reproductive system is crucial for advancing knowledge of reproductive biology and improving productivity in certain domesticated bird species (Johnson, 2014; Yaseen *et al.,* 2024; Obaid *et al.,* 2020).

The common wood or stock pigeon (*Columba oenas*), belonging to the family Columbidae (pigeons and doves), is identifiable by its blue-grey plumage marked with black wing spots. Males typically measure 32-34 cm in body length and weigh between 303-365 g, while females weigh approximately 286-290 g (BirdLife DataZone, 2023). In Iraq, the species is prevalent in the northern and central regions, favoring habitats such as open woodlands, farmlands with scattered trees and hedgerows (Al-Mansour and Al-Zghoul, 2020).

The female avian reproductive system differs notably from that of most mammals. While mammals typically possess paired ovaries and uterine horns, female birds develop only a single functional ovary and oviduct (left side), as the right ovary and oviduct regress during embryonic development (Onagbesan *et al.,* 2009; Obaid *et al.,* 2020; Kareem *et al.,* 2023). The avian oviduct comprises five distinct regions: infundibulum, magnum, isthmus, uterus and vagina. Each of these parts performs specialized functions during the activity of the oviduct, including the processes from reception of the egg to its laying (Sasanami *et al.,* 2013; Altemeemi *et al.,* 2021; Al-Khuzaay *et al.,* 2024). The anatomical and histological characteristics of the female reproductive system in birds are influenced by physiological conditions and vary with the breeding season (van der Klein *et al.,* 2020). During the egg-laying phase, the ovary and the oviduct undergo a major structural remodeling driven by hormonal fluctuations associated with ovulation (Hrabia *et al.,* 2021). Similar physiological adaptations have been observed in other bird species, such as ducks and emu (Kim *et al.,* 2016; Vijayakumar *et al.,* 2016). Furthermore, inter-species textural differences, including Turkey and ostrich, have been documented, especially in infundibulum, magnum isthmus and uterus (Yahya *et al.,* 2024; Hameed *et al.,* 2025). However, detailed anatomical and tissue information on the Columba oenas oviduct during the egg-laying period is still limited compared to other pigeon species previously studied. This study aimed to investigate that of the gross and and microscopic female reproductive system in Stock Doves (*Columba oenas*) during the egg-laying phase. Focus was placed on the ovary and individual oviduct segments to identify morphological and histological features associated with functional specialization for egg formation in this species.

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How to cite this article: Wahab, S.A.M.A. (2025). Anatomical and Histological Study of the Female Reproductive System (*Columba oenas*) during the Egg-laying Period. *Asian Journal of Dairy and Food Research*. **44 (Special Issue):** 199-209. doi: 10.18805/ajdfr.DRF-578.

Submitted: 24-07-2025 **Accepted:** 14-10-2025 **Online:** 21-11-2025

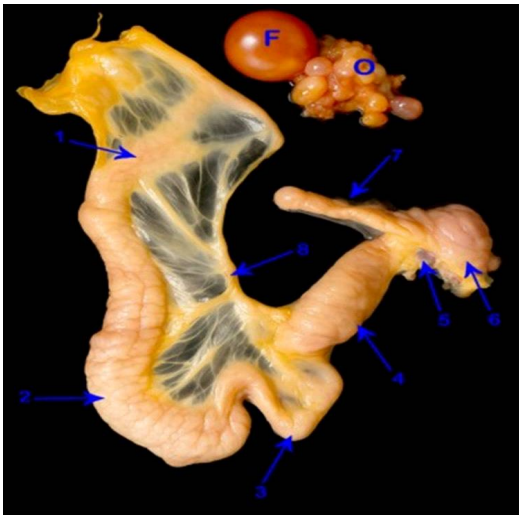
MATERIALS AND METHODS

Samples

This study utilized fifteen (15) adult female Stock Doves (*Columba oenas*) during the egg-laying period (March to May), with an average body weight range of 270-285 g. Birds were obtained from local markets and maintained under standard management conditions: Temperature (22-25°C), photoperiod (14 h light:10 h dark) and appropriate nutrition. The bird were confirmed to be in the laying phase through reproductive behavior observation and post-mortem examination of the reproductive system. The study adhered to institutional ethical standards for laboratory animal care and use.

Anatomical study

Birds were anesthetized using chloroform and humanely euthanized. After opening the abdominal cavity, the entire female reproductive system (ovary and oviduct) was carefully excised. Gross anatomical observations were recorded and photographed. Morphometric measurements were taken using a calibrated ruler and digital calipers, recording: Length of each oviduct segment (mm), Weight of each segment (g), Diameter of each segment (mm), Number of mucosal folds per segment and Height and width of mucosal folds (μm).



(F): large preovulatory follicles with smooth, glistening surfaces, indicating imminent vulation; (O): Ovary containing follicles at various stages of development; (1) Infundibulum; (2) Magnum: The longest and thickest part of the oviduct; (3) Isthmus; (4) Uterus (shell gland); (5) Vagina: A short terminal segment aiding in egg passage into the cloaca; (6) Cloaca; (7) Reduced right oviduct: A rudimentary and nonfunctional oviduct remnant; (8) Dorsal mesentery of the oviduct.

Fig 1: Genital apparatus of a laying *Columba oenas* (gastrointestinal tract removed), This image shows the left reproductive system of an adult laying *Columba oenas* female with the gastrointestinal tract removed for anatomical clarity.

Histological study

Small samples (0.5 cm) were collected from the ovary and each oviduct segment (infundibulum, magnum, isthmus, uterus, vagina). Samples were fixed in 10% neutral buffered formalin for 48 hours, washed in running water, dehydrated through graded ethanol series (70%, 80%, 90%, 95%, 100%), cleared in xylene, embedded in paraffin wax and sectioned at 5 μm thickness using a rotary microtome. For general histology, the sections were stained with: Hematoxylin and Eosin, for neutral carbohydrates stained by periodic acid-schiff (PAS) and alcian blue (AB) for acidic carbohydrates.

Histomorphometry analysis

light microscope with an attached digital camera used for Sections examination. The following measurements were made using ImageJ software: Epithelial thickness (μm), mucosal fold height (μm), Mucosal fold width (μm), submucosal layer thickness (μm) and muscular layer thickness (μm).

Statistical analysis

Statistical analysis was performed by SPSS 25. For all data, means and standard deviations were obtained. Comparison between the various segments of the oviduct was performed by one-way ANOVA followed by Tukey's test for multiple comparisons. $P<0.05$ was statistically significant.

RESULTS AND DISCUSSION

Gross anatomy of the female reproductive system

Gross examination revealed a functional left ovary and left oviduct, with the right ovary and oviduct being vestigial (Fig 1). The left ovary was located dorsally in the abdominal cavity anterior to the left kidney, appearing cluster-like with ovarian follicles at various developmental stages, ranging from small primary follicles to large mature yellow follicles.

The oviduct consisted of five anatomically distinct segments from anterior to posterior: Infundibulum, Magnum, Isthmus, Uterus and Vagina (Fig 1). The infundibulum formed a funnel receiving the ovulated ovum; the magnum was the longest segment; the isthmus had a relatively smaller diameter; the uterus was the most dilated; and the short vagina opened into the cloaca.

The gross morphometric measurements of the different segments of the oviduct (Table 1). The results showed significant differences ($P<0.05$) in the measurements among the various segments. The magnum was the longest segment, with an average length of 41.24±0.55 mm, while the infundibulum was the shortest, with an average length of 22.43±0.72 mm. The uterus was the heaviest segment, weighing 455.8±0.83 g, whereas the infundibulum was the lightest at 67.8±0.79 g. Regarding diameter, the magnum had the largest average diameter at 425.43±0.35 mm, while the infundibulum had the smallest at 50.63±0.48 mm.

Histology of the ovary

Histologically the ovary is composed of an outer cortex and an inner medulla that is vascular (Fig 2A). The cortex contained follicles at various stages: Primary follicles with a single layer of granulosa cells and secondary follicles with multilayered granulosa cells (Fig 2B). Mature follicles exhibited a single layer of granulosa cells, a vascular theca interna and a fibrous theca externa (Fig 2C). The medulla contained blood vessels, connective tissue and nerves (Fig 2D).

Histology of the oviduct

Infundibulum

The infundibular wall comprised of four layers: *Tunica mucosa*, *T. submucosa*, *T. muscularis* and *T. serosa* (Fig 3A). The mucosa featured finger-like folds (Fig 3B) lined by simple columnar epithelium with ciliated and non-ciliated cells (Fig 3C). The lamina propria had scattered lymphoid nodules and mucous glands (Fig 3D). The muscularis was relatively thin, with inner circular and outer longitudinal layers.

Table 2 presents the histological measurements of the oviduct. The mean epithelial thickness of the infundibulum was 18.45±0.33 µm, the submucosal thickness was 28.71±0.47 µm and the muscular layer thickness was 65.38±0.56 µm. The mean height of the mucosal folds was 310.25±0.82 µm and their width was 82.46±0.63 µm.

Magnum

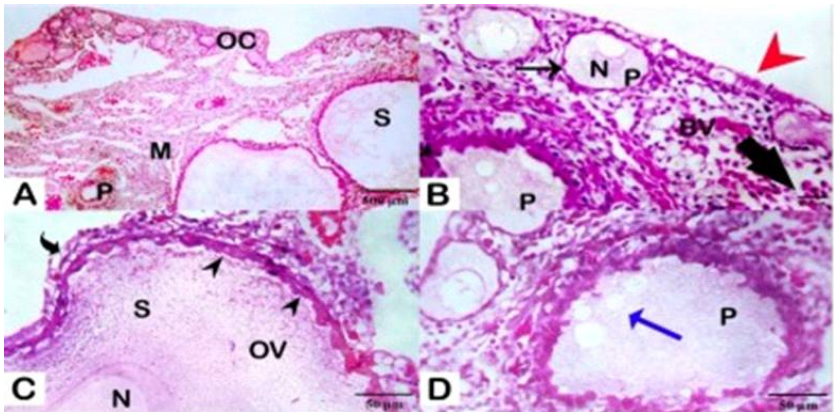
The magnum wall showed four distinct layers (Fig 4A). The mucosa exhibited long, broad, leaf-like folds (Fig 4B). The lamina propria contained numerous PAS-positive secretory glands (Fig 4C). The surface epithelium was tall columnar with ciliated and non-ciliated cells (Fig 4D). The muscularis was thicker than in the infundibulum.

According to the histological measurements (Table 2), the mean epithelial thickness of the magnum was

Table 1: Gross morphometric measurements of oviduct segments in *Columba oenas* during egg-laying.

Part of oviduct	Length (cm) M ± SE (Range)	Weight (gm) M ± SE (Range)	Diameter (mm) M ± SE (Range)
Infundibulum	1.54±0.10^{a} (1.4-2.3)	0.52±0.05^{a} (0.47-0.57)	6.23±0.23^{a} (5.8-6.7)
Magnum	9.88±0.71^{b} (7.6-10.3)	1.69±0.10^{b} (1.54-1.79)	11.73±0.21^{b} (11.3-12.1)
Isthmus	4.64±0.21^{c} (4.4-5.3)	0.90±0.03^{c} (0.77-0.93)	7.32±0.14^{c} (7.0-7.6)
Uterus	2.7±0.24^{d} (1.7-2.9)	1.83±0.12^{bd} (1.71-1.95)	15.4±0.24^{d} (15.0-15.8)
Vagina	1.54±0.14^{a} (1.2-1.9)	0.86±0.06^{c} (0.80-0.92)	11.29±0.30^{b} (10.8-11.7)

Data are expressed as means ± SE with ranges in parentheses. Dissimilar superscript letters indicate significant differences at $P<0.05$: (a) significantly different from the magnum value; (b) significantly different from the infundibulum value; (c) significantly different from the uterus value; (d) significantly different from the isthmus value; (e) significantly different from the vagina value.



(A) showing the ovary composed of outer ovarian cortex (OC) and inner vascular medulla; (M): the cortex was occupied by different developmental stages of ovarian follicles; primary follicles; (P): secondary follicles; (S): scale bar: 500 µm. B): showing the ovary covered by simple cuboidal epithelium (red arrowhead), the tunica albuginea (thick arrow), the primary follicle; (P): the nucleus of the primary oocyte (N), the follicular epithelium (arrow) scale bar: 100µm. (C) showing secondary ovarian follicle (S) with central nucleus (N): Ooplasm (OV) and lined with double layer of granulosa cells (black arrowhead) and surrounded with theca layer (closed arrow) scale bar: 50 µm. (D) showing primary follicle with ooplasm containing empty vesicles (blue arrow) scale bar: 50 µm. Stain: H and E.

Fig 2: A photomicrograph of female *Columba oenas* ovary.

32.63±0.42 µm, which was significantly greater (P<0.05) than that of the infundibulum. The mean thickness of the submucosal layer was 175.34±0.75 µm and the muscular layer measured 125.82±0.68 µm. The mean height of the mucosal folds was 650.53±0.94 µm and their width was 195.76±0.85 µm, both of which were significantly greater (P<0.05) than those in the infundibulum.

Isthmus

The isthmus displayed a star-shaped lumen (Fig 5A), pseudostratified columnar epithelium (Fig 5B) and moderately PAS-positive secretory glands (Fig 5C). Blood vessels were observed in the submucosa (Fig 5D).

According to the histological measurements (Table 2), the mean epithelial thickness of the isthmus was 25.19±0.38 µm, the submucosal layer thickness was 90.54±0.63 µm and the muscular layer thickness was 130.47±0.72 µm. The mean height of the mucosal folds was 410.36±0.86 µm and their width was 120.83±0.74 µm.

Uterus

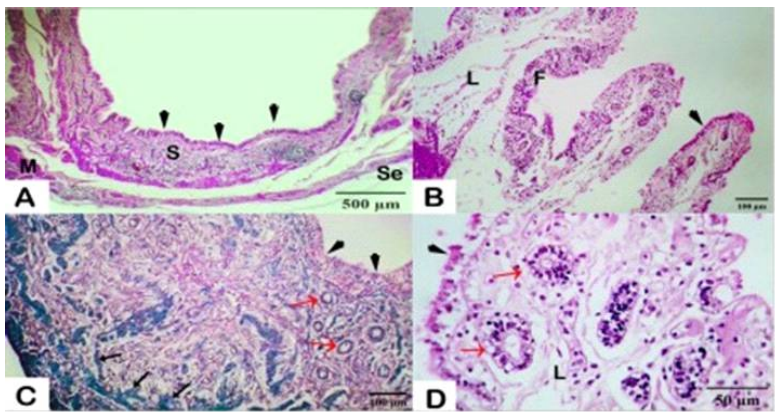
The uterine mucosa showed branched, complex folds (Fig 6A) and abundant branched tubular glands positive for PAS and AB (Fig 6B, C). The epithelium was ciliated (Fig 6D). The submucosa was highly vascularized.

According to the histological measurements (Table 2), the mean epithelial thickness of the uterus was 20.81±0.35 µm and the submucosal layer thickness was 250.65±0.82 µm, which was significantly the highest (P<0.05) among all oviduct segments. The muscular layer measured 180.37±0.77 µm. The mean height of the mucosal folds was 480.72±0.91 µm and their width was 170.58±0.81 µm.

Table 2: Histomorphometric measurements (µm) of oviduct segments in *Columba oenas* during egg-laying.

Part	Folds number (mm^2)	Folds height (µm)	Folds width (µm)	Epithelium height (µm)	Tunica submucosa thickness (µm)	Tunica muscularis thickness (µm)
Infundibulum	22.43±0.72[a]	83.5±0.31[a]	50.63±0.48[a]	23.73±0.62[a]	67.8±0.79[a]	150.33±0.41[a]
Magnum	41.24±0.55[b]	205.7±0.77[b]	425.43±0.35[b]	33.18±0.54[b]	235.3±0.39[b]	74.21±0.27[b]
Isthmus	37.64±0.33[c]	325.8±0.47[c]	85.37±0.69[c]	78.25±0.44[c]	225.9±0.68[b]	530.16±0.52[c]
Uterus	45.31±0.53[d]	1760.4±0.41[d]	360.77±0.75[d]	40.42±0.30[d]	420.5±0.59[c]	535.73±0.58[c]
Vagina	29.7±0.62[bd]	465.3±0.29[e]	180.9±0.40[e]	27.63±0.56[ab]	455.8±0.83[c]	720.48±0.34[d]

Data are expressed as means ± SD with dissimilar superscript letters (significantly differing at P<0.05): (a) significantly different from the vagina value; (b) significantly different from the uterus value; (c) significantly different from the isthmus value; (d) significantly different from the magnum value; (e) significantly different from the infundibulum value.



(A): The vaginal wall is composed of three main layers: *T. mucosa* (arrowheads), *T. submucosa* (S) and *T. muscularis* (M), surrounded externally by *T. serosa* (Se). (H and E stain, scale bar: 500 µm). (B): The *Tunica mucosa* is extensively folded into anastomosing finger-like projections (F), supported by the lamina propria (L). The surface epithelium (arrowheads) appears simple columnar with regional specializations. (H and E stain, scale bar: 100 µm). (C): The surface epithelium (arrowheads) and underlying branched mucosal glands (red arrows) are visible within the lamina propria, with delicate collagen fibers stained blue (black arrows). (Crossmon's Trichrome stain, scale bar: 100 µm). (D): Higher magnification of the epithelialis mucosa (arrowheads) reveals simple ciliated and non-ciliated tall columnar - cells with acidophilic cytoplasm, and oval vesicular nuclei and. The mucosal glands (red arrows) are also observed. A lymphoid nodule (L) is present within the lamina propria. (H and E stain, scale bar: 50 µm).

Fig 3: Photomicrographs of the infundibulum part of the oviduct of adult female *Columba oenas* showing.

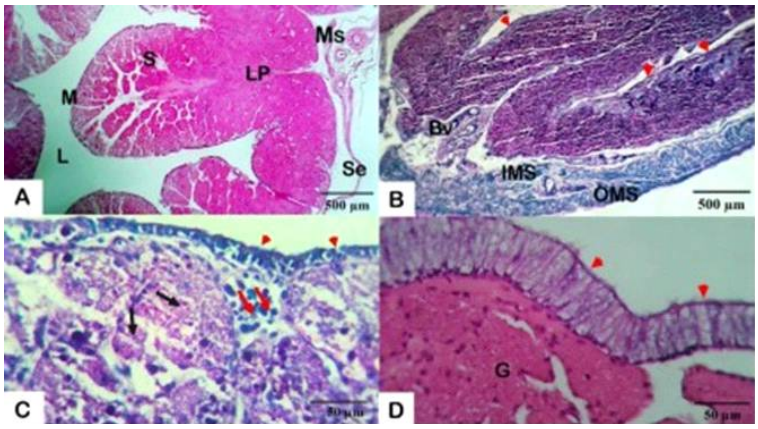
Vagina

The vaginal mucosa featured longitudinal folds (Fig 7A) lined by simple/pseudostratified columnar epithelium (Fig 7B). Branched tubular glands opened into the lumen (Fig 7C) and showed strong AB-positivity with dark blue acidic mucin granules (Fig 7D). The muscularis was exceptionally thick.

According to the histological measurements (Table 2), the mean epithelial thickness of the vagina was 28.35±0.39 µm, the submucosal layer thickness was 45.28±0.54 µm and the muscular layer thickness was 195.43±0.79 µm, which was significantly the highest (P<0.05) among all oviduct segments. The mean height of the mucosal folds was 380.45±0.84 µm and their width was 110.27±0.71 µm.

The results of the current study showed that the female reproductive system in *Columba oenas* consists solely of the left ovary and oviduct, while the right side is regressed. This feature is consistent with the findings of King and McLelland (1984), who noted that most bird species possess only a functional left ovary and oviduct, except for some birds such as falcons, which may retain a partially developed right reproductive tract. In a rare case, Kinsky (1971) reported the presence of paired ovaries in the kiwi (*Apteryx*). The stockdove (*Columba oenas*) is widespread in western and northwestern Iraq (Salim *et al.,* 2012). The anatomical measurements in our study align with those of Al-Dokhiel (2011) on the domestic pigeon (*Columba livia*), particularly in terms of the relative order of lengths and diameters of the oviductal segments, although absolute values differ due to species-specific variation. The study observed that the magnum is the longest segment of the oviduct (representing 48.7% of the total length), while the uterus has the largest diameter. This agrees with Carreiro *et al.* (2021), who also found such similarities in domestic pigeons. These differences are associated with different functions of adaptation from each segment's need to perform: the magnum for its secretory function (albumen) needs a large secretory surface, while the uterus needs to be able to accommodate the egg through shell formation (Chousalkar *et al.,* 2010; Abd El-Rahmana *et al.,* 2024; Al-Maliki *et al.,* 2025).

The ovary at time of ovulation was histologically characterized by follicles at different stages of development in the outer cortex, indicative of continuous and synchronous ovarian function. This fits in accordance with Johnson (2014), wherein the avian ovary was characterized by staged follicular growth The presented results agree with Johnson (2014), who described ache to for hierarchically staged follicular growth by the avian ovary. The existence of primordial, primary and secondary and mature follicles simultaneously is an indication of the cyclic nature of pigeon ovarian activity. Onagbesan *et al.* (2009) have also reported that the follicular dynamics in birds enables egg production for continuous periods. A recent transcriptome study by Zhang *et al.* (2023) in domestic pigeons. Also, during the different developmental stages of the follicles, noticeable patterns of gene expression



(A): The magnum wall is composed of four distinct tunics: *T. mucosa* (M), *T. submucosa* (S), *T. muscularis* (Ms) and *T. serosa* (Se). Note the narrow lumen (L). Hematoxylin and Eosin (H&E) stain. Scale bar: 500 µm. (B): The mucosal layer shows long, broad, leaf-like folds with deep surface invaginations (arrowheads). Combined periodic acid-schiff and alcian blue (PAS and AB) stain. Scale bar: 500 µm. (C): The lamina propria contains numerous secretory glands (red arrows) that show strong positive reaction to PAS stain, while some exhausted glands (black arrows) are negative. Surface epithelial cells (arrowheads) are also PAS-positive. PAS & AB stain. Scale bar: 50 µm. (D): The surface epithelium consists of simple tall columnar cells, both ciliated and non-ciliated (arrowheads). The mucosal tubular glands (G) occupy most of the magnum wall's thickness. H and E stain. Scale bar: 50 µm.

Fig 4: Photomicrographs of the magnum region of the adult female *Columba oenas* oviduct.

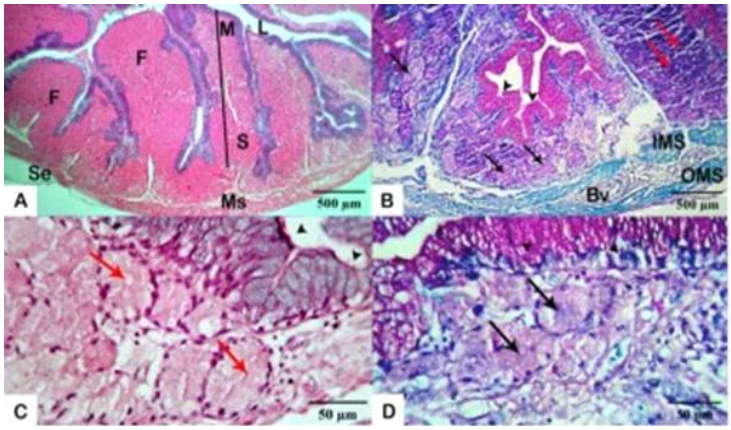
specific to follicular development stages were reported. Germinal vesicle and mature follicles displayed deposition vacuoles in the ooplasm yolk, like the findings of Rahman *et al.* (2019) in Japanese quail. The yolk nourishes the growing embryo. Stephens and Johnson (2019) emphasized the crucial role of egg yolk accumulation in determining egg quality and fertility.

The infundibulum featured branched finger-like mucosal folds composed of ciliated columnar epithelium. According to Bakst and Akuffo (2019) this structure is conducive to interception of the ovulated oocyte. Interestingly, lymphoid nodules were seen in the lamina propria, corroborating Madekurozwa (2016) who reported innate defense protection in the reproductive tract. The sperm storage tubules are also present in the infundibulum, as has been described by Martínez *et al.* (2017) that carry out sperm storage over weeks to fertilize multiple oocytes.

The magnum exhibited long, leaf-like mucosal folds and highly branched tubular glands in the lamina propria, which were consistent with those described by El-Sayed *et al.* (2021). Intense PAS-positive reactions were observed, which presumably indicate the secretion of glycoproteins involved in egg white formation) are responsible for the secretion of 40-50% of egg white proteins such as albumin, ovomucoid, lysozyme and other such, antimicrobial and antiviral proteins (Rahman and Sasanami, 2020). The longer magnum and its thick glandular organization might be because the major secretory function is developed, because under this part, the egg is kept for 4-5 hr (Sasanami *et al.,* 2013; Razooki *et al.,* 2025; Jasim *et al.,* 2025).

The isthmus had wide mucosal folds and a stellate lumen lined by pseudostratified columnar epithelium and PAS-positive secretory glands. These characteristics are consistent with those of Hassan *et al.* (2019) and these generated isthmus compartments have been reported to include shell membrane-secreting cells in the epithelium of the isthmus (Razooki *et al.,* 2019). The glands are important to produce fibrous proteins that contribute to inner and outer shell membranes. As reported by Chousalkar *et al.* (2010), such membranes are composed of collagen, keratins and proteoglycans, which provide substrate for the calcium carbonate deposition. Our findings corroborate that the isthmus is involved in initial calcium salt deposition, as described by Chen *et al.* (2018); Mirhish and Nasif, (2013).

The uterus showed deep branched mucosal folds, ciliated columnar epithelium and branched tubular glands with strong PAS and Alcian blue staining. This histological pattern reveals the complex functioning of the uterus related to shell formation and agrees with Gómez *et al.* (2019). Uterine glands play a crucial role in the transport of calcium and carbonate ions necessary for the calcium carbonate shell, which represents 95% of the total shell weight. Reynolds *et al.* (2017) drew attention to the relationship between calcium metabolism and avian reproduction, where dietary sources and skeletal structures provide the necessary calcium. The uterus is another source of



(A): Four distinct layers of the isthmus wall: *T. mucosa* (M) with broad primary mucosal folds (F), *T. submucosa* (S), *T. muscularis* (Ms) and *T. serosa* (Se). (H and E stain, scale bar: 500 µm). (B): The mucosal folds (F) create a characteristic star-shaped lumen. The surface epithelial cells (arrowheads) and active secretory glands (red arrows) show strong positive reaction, while the exhausted glands (black arrows) appear negative with PAS. Blood vessel (Bv), inner muscularis (IMS) and outer muscularis (OMS) are also observed. (AB/PAS stain, scale bar: 500 µm). (C): The epithelium of the mucosa consists of pseudostratified columnar cells, and the secretory glands are indicated (red arrows). (Hematoxylin and Eosin stain, scale bar: 50 µm). (D): The surface epithelium (arrowheads) and underlying tubular mucosal glands (black arrows) occupy most of the mucosal thickness, exhibiting strong positive staining with PAS. (Combined AB/PAS stain, scale bar: 50 µm).

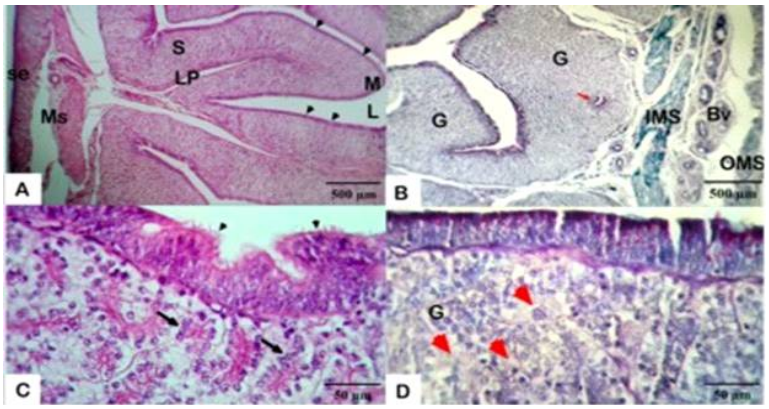
Fig 5: Photomicrographs of the isthmus part of the oviduct in adult female *Columba oenas* showing.

pigments to the shell, which may explain the presence of glands that produce both neutral and acidic mucins. The results correspond with those of Carreiro *et al.* (2021) and Ibrahim *et al.* (2015), who stressed the multifunctional role of uterine glands in pigeons.

The results of the study revealed deep longitudinal mucosal folds, a thick muscularis, particularly the longitudinal layer and branched glands positive to PAS and AB in the vagina. The longitudinal folds in the station increase the area and help with lubrication and the smooth passage of the egg. Analogous structures were described by Gómez *et al.* (2019), who emphasized their protective and secretory capacities. The thick muscular layer, especially the longitudinal muscle layer, allows forcing strong peristaltic contractions, which are essential for the expulsion of egg. Wang *et al.* (2014) reported the importance of the vaginal smooth muscles involving in the transportation of the egg from the ovary to the cloaca. Moreover, the vagina is involved in spermicide and immunity. The vagnial environment is known to serve as a selective barrier for healthy sperm before they get to the sperm storage tubules (Bakst and Akuffo, 2019). Positive PAS- and Alcian blue-stained glands indicate the production of mucus performing a role both mechanical and immunologic (Gómez *et al.,* 2019; Razooki *et al.,* 2020). The vagina also contributes to the immune system's selection of sperm as only healthy sperm through mechanisms were described by Bakst and Akuffo (2019) can reach storage tubules of the infundibulum, this results in quality (Gupta and Bakst, 1993). The intense PAS and Alcian blue reactivity of the glands indicates that they secrete mixed mucins, as described by Gómez *et al.* (2019) who reported on its protective mechanical and immunological role in the process of egg laying.

Histological features were significantly different among oviductal segments in the present study (Table 2), which reflects the different functions of the segments in egg production. These results are consistent with Al-Mansour and Al-Zghoul (2020), who highlighted the relationship between the histological, physiological and biological function of the oviduct in the Eurasian collared dove. Epithelial thickness was greatest in the uterus (45.31±0.53 µm), followed by the magnum (41.24±0.55 µm), correlating with their secretory activity. Mucosal folds were longest in the uterus (1760.4±0.41 µm), increasing surface area for ion exchange during shell formation. (El-Sayed *et al.,* 2021; Salam *et al.,* 2025; Abass *et al.,* 2025) linked fold length with secretory intensity. Gland diameter was largest in the magnum (425.43±0.35 µm), followed by the uterus (360.77±0.75 µm), consistent with their roles in secreting proteins and calcium, respectively.

Hassan *et al.* (2019) also described that hypertrophy of glandular cells observed in these segments is influenced by increased estrogen and progesterone at the time of



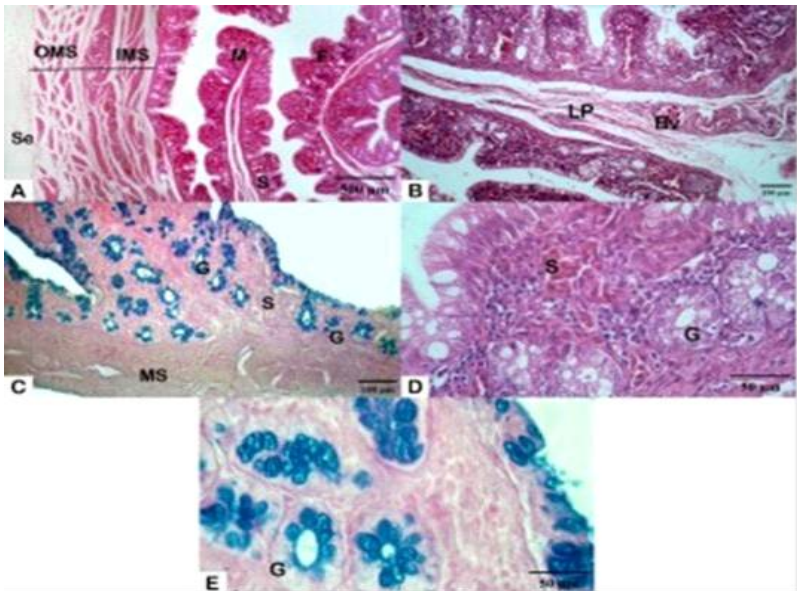
(A): Four tunics forming the uterine wall; *T. mucosa* (M), *T. submucosa* (S), *T. muscularis* (Ms) and *T. serosa* (Se), The uterine mucosal folds are divided by prominent grooves (arrows), Lamina propria (LP), lumen (L), H and E stain, scale bar: 500 µm. (B): uterine glands (G) occupying much of the mucosal area, with intense magenta and bluish staining indicating the presence of both neutral and acidic mucopolysaccharides. The red arrow indicates a central secretory structure within a gland. Inner muscularis (IMS) and outer muscularis (OMS) layers are clearly visible, separated by intervening connective tissue. A blood vessel (Bv) is seen adjacent to the muscular layers. (AB/PAS) stain, Scale bar: 500 µm. (C): showing the columnar epithelial lining with apical cilia (arrowheads) and underlying branched tubular glands (black arrows) occupying the lamina propria. H and E stain, scale bar: 50 µm (D): highlighting the epithelial lining rich in mucopolysaccharides, with glandular secretions (G) displaying mixed acidic and neutral mucins (red arrowheads). The staining emphasizes the mucus-producing activity of the glandular cells. (AB/PAS) stain, Scale bar: 50 µm.

Fig 6: Photomicrographs of the uterus part of adult female *Columba oenas* oviduct showing.

egg-laying. The muscular layer was largest in the vagina and the uterus, the longitudinal muscle (455.8±0.83 and 420.5±0.59 µm, respectively), supporting the crucial role in egg transpor. Wang *et al.* (2014) have pointed out the requirement of powerful smooth muscles for egg-propulsion, especially after the completion of the shell.

Increased estrogen levels induce the development of the epithelial gland, progesterone is responsible for secretory activity and growth of the smooth muscle. Nakamura *et al.* (2021) highlighted the effect of progesterone on glandular development, notably in the magnum and uterus (Williams, 2012; van der Klein *et al.,* 2020). Prolactin is also involved in reproductive activities such as follicular development and glandular function (Hrabia *et al.,* 2021) and further demonstrated by (Smith *et al*., 2020; Ghiath *et al.,* 2025). The expansion and increasing complexity of the gland during oviposition reflects hormonal response as described by Patel *et al.* (2010) who reported histological and biochemical ovarian alterations of domestic pigeons due to reproduction.

The female reproductive system in Columba oenas: Anatomical, histological and immunohistochemical study the anatomical and histological structures of the female reproductive system in *Columba oenas* were found to be like those in other birds, but with some species-specific character. The magnum accounts for a large amount in the oviduct length and then in domesticated chicken as observed by Nabil *et al.* (2022), indicating its functional specilization. The vaginal muscle layer in pigeons is thicker than that in quail, similar to that found in larger birds (Al-Dokhiel, 2011; Hmeed *et al.,* 2025; Al-Mashhadani *et al.,* 2024). Comparison with Al-Mansour and Al-Zghoul (2020)



(A): The vaginal wall is composed of four distinct tunics: *T. mucosa* (M), *T. submucosa* (S), T.muscularis (MS) and *T. serosa* (Se). The mucosal surface forms moderate to deep longitudinal folds (F), separated by narrow grooves, contributing to the increased surface area. The surface epithelium (S) is simple columnar or pseudostratified columnar in appearance. Both inner (IMS) and outer muscularis (OMS) layers are distinctly visible. H and E stain, scale bar: 500 µm. (B): The lamina propria (LP) is well vascularized and houses branched tubular glands (G) extending deeply into the mucosa. These glands exhibit strong magenta and bluish staining, indicating the presence of both neutral and acidic mucopolysaccharides, suggestive of active mucin secretion. The blood vessel (BV) lies adjacent to the muscular layers, while connective tissue separates the IMS and OMS. H and E stain, scale bar: 100 µm. (C): The mucosal epithelium appears columnar with some apical cilia, aiding in mucosal transport. The underlying branched glands (G) extend into the lamina propria, suggesting high secretory function. (AB/PAS stain, scale bar: 100 µm. (D): A higher magnification reveals mixed mucins (neutral and acidic) within the glandular lumen (G), as shown by the intense magenta and blue coloration. The surface epithelium (S) appears active in secretion, supported by the intense mucopolysaccharide staining. H and E stain, scale bar: 50 µm. (E): High magnification of the glandular structure (G) shows dark, blue-stained granules rich in acidic mucins, supporting a protective and lubricative role for vaginal secretions, particularly important during oviposition. (AB/PAS stain, scale bar: 50 µm).

Fig 7: Photomicrographs of the vaginal part of adult female *Columba oenas* oviduct showing.

on the Eurasian collared dove revealed closely resembling structure of the oviduct with some differences in the size of mucosal folds and thickness of musculature, presumably attributable to phylogenetic distance. However, other research on phylogenetically more distant birds (*e.g.*, Madekurozwa, 2016, on ostriches) show more pronounced structural dissimilarities, especially in sperm storage tubule layout and gland distribution, which suggest greater evolutionary divergent.

CONCLUSION AND RECOMMENDATION

1. The female reproductive tract of Columba oenas is clearly adapted for egg-laying and provides accounts of the histological structure that must ensure the specialized functions of each oviductal parts during the egg formation.
2. Histological examination demonstrated that there were significant differences of the type of epithelium, structure of mucosal folds, glands and muscle thickness between segments of the oviduct, which are conducive to their supporting crucial role in secretion, transport and calcification.
3. The study recommends comparative evaluation of the reproductive tract in different reproductive stages and correlating these changes with hormonal fluctuations (estrogen, progesterone, prolactin).
4. The use of advanced techniques such as electron microscopy, immunohistochemistry and 3D imaging is encouraged to explore microstructural and molecular mechanisms governing egg formation and reproductive function.

Novelty statement

Despite the extensive research on the reproductive systems of domestic avian species, there remains a notable scarcity of detailed anatomical and histological data regarding the female reproductive tract of wild pigeons, particularly the Stock Dove (*Columba oenas*) during the egg-laying period. To our knowledge, this is the first comprehensive study to document the gross morphology and microanatomy of the ovary and oviduct in *Columba oenas* in correlation with its reproductive cycle. This work provides novel insights into the segmental structure, glandular distribution, epithelial variations and functional specialization of the oviduct during peak reproductive activity. The findings contribute significantly to the comparative anatomy of wild columbids and offer a valuable baseline for future ecological, physiological and conservation-oriented studies.

Data availability statement

All data generated or analyzed during this study are included in the published article. Additional supporting materials are available from the corresponding author upon reasonable request.

Conflict of interest

The author warrants that there is no conflict of interest in the manuscript.

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