MORPHOLOGICAL ASPECTS OF THE OSTRICH INFUNDIBULUM AND MAGNUM

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Summary

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The rationale of the current research work was to throw more light on the anatomy, the histological features as well as some histochemical aspects of the ostrich infundibulum and magnum at different developmental ages. Grossly, the infundibulum in immature ostrich chicks was not yet well differentiated into funnel and neck parts, but in laying ostrich hens it was subdivided into large infundibular funnel and neck regions. In addition the magnum was highly flexuous in laying hens. However microscopically, paraffin sections (5–7 μm thick) of infundibulum and magnum were stained and examined. We showed that the mucosa in both infundibulum and magnum was modified into variable mucosal folds, and the shape of the folds were region-dependent. As well as the branching and rebranching of mucosal folds and their complexity in shape increased with advancement of age. Furthermore, the mucosal glands started to appear in pre-laying ostriches as a glandular budding, which increased in number, size and branching, until they filled the whole mucosal folds leaving thin connective tissue strand submucosa. The present study described for the first time the developmental changes of ostrich infundibulum and magnum.

Key words: infundibulum, histochemistry, magnum, ostrich, oviduct

INTRODUCTION

During sexual development, the oviduct of the ostrich undergoes different morphological changes and a process of maturation under the effect of pituitary gonadal hormones. There is an increasing interest in studying the reproductive system of wild birds, in order to improve their production and reproduction efficacy and to keep their species. The ostrich (*Struthio camelus*) is a wild bird, the only species of the family Struthionidae and is the largest living bird. The ostrich meat is characterised by low cholesterol and low intramuscular fat contents, so patients with heart and vascular diseases are advised to consume it (Sales, 1995).

The morphology and the physiology of the avian oviduct have been studied for many years, especially in domestic fowl species. The developing egg remained for 9 h in the proximal part (infundibulum, magnum or isthmus) and for 39 h in the distal part of the oviduct (uterus) during the egg laying cycle (Bronneberg *et al.*, 2006).

The aim of our work was to study the anatomy, the histological features as well as some histochemical aspects of the ostrich infundibulum and magnum at different developmental ages.

MATERIALS AND METHODS

Animals

Four age groups of female ostriches (*Struthio camelus*) were used for this study, selected on the basis of the records of ostrich farms: El-Nakheel, El-Masria, El-Holandyia and Military Forces farms in Egypt. Each age group included six birds. The birds in groups were 8–10, 15, 36–42 and 60–72 month-old. The oviducts were immediately collected after slaughter or accidental death of the birds.

Histological investigations

The oviducts were cross sectionned into oviductal regions: infundibulum, magnum, isthmus, uterus and vagina. The infundibula from the left oviduct of each bird were taken just after sacrifice and evisceration, then immediately fixed in 10% neutral buffered formalin and routinely processed and embedded in paraffin. Paraffin sections (5–7 μm) were stained with Harr's haematoxylin and eosin for general histological studies. The other used staining techniques were Crossman's trichrome for demonstration of collagen fibres and smooth muscles (Crossman, 1937), Periodic acid Schiff (PAS) for visualisation of neutral mucopolysaccharides (McManus, 1946), alcian blue (pH 2.5) for visualisation of acid mucopolysaccharides (Steedman, 1950), Silver impregnation technique for visualisation of reticular fibres (Gomori, 1937).

Morphometrical investigations

At least three samples from infundibula of different ostriches were prepared from each age. By means of a light microscope and an eye piece micrometer disc (ocular micrometer), the height of the infundibular mucosal folds, the diameter of infun-

dibular and magnal proprial glands were measured in comparison to isthmus and uterus at different ages.

For determination of significant differences, the unpaired *t*-test or one-way ANOVA for multiple comparisons was used. P values ≤ 0.05 were considered to be significant.

RESULTS

Gross anatomy of the infundibulum and the magnum

The left oviduct of the ostrich predominated and the right one was rudimental at the right side of the coelom. The left oviduct appeared as convoluted thick-walled tube, extended from the vicinity of the left ovary to the cloacae. In 72 month-old hens (laying hens), its length ranged from 122–157 cm with a weight varying from 0.9 to 1.8 kg. The oviduct was fixed by a dorsal and a ventral peritoneal ligament to the abdominal coelom. The infundibulum in immature birds (8–15-month-old) was a very short less differentiated tube-like structure. Meanwhile, in pre-laying hens (36–42 month-old), the infundibulum started to be well differentiated into two main regions – a funnel part and a tubular part (infundibular neck). The funnel part was the widest. It is thin-walled, funnel–shaped, measuring 9.0 to 15 cm in length and 18 to 23 cm in width in the laying hens (72 month-old). In pre-laying hens (36–42 months of age), it ranged from 3.0 to 4.0 cm in length and 6.0 to 8.5 cm in width.

The infundibular funnel had a thin wall, which gradually increased in thickness towards the tubal part. Near the left ovary, the abdominal orifice of the oviduct was a wide slit-like opening. The mucosa of the infundibular funnel in
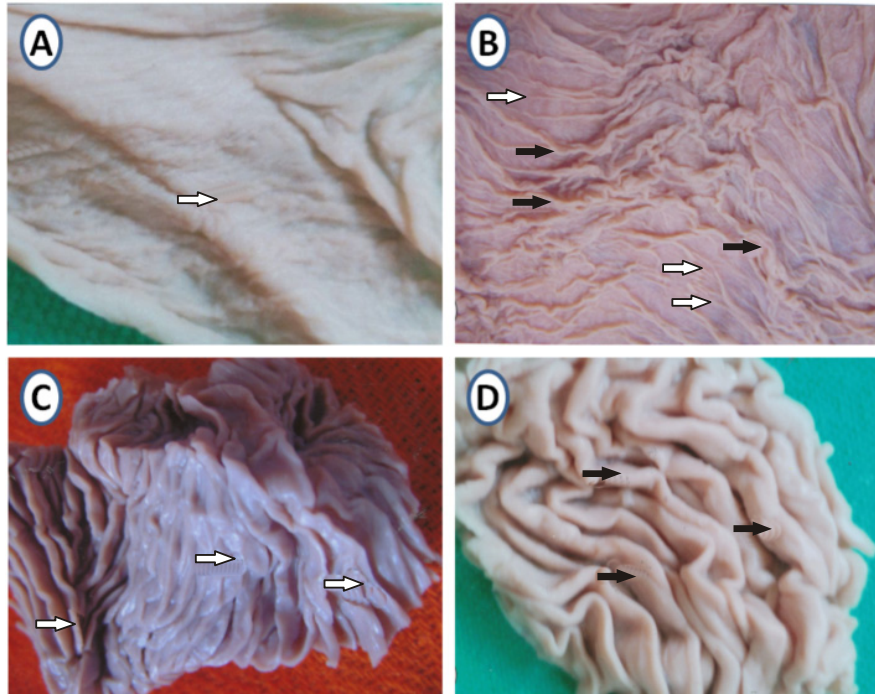
Fig. 1. A. Infundibular funnel of a laying ostrich hen – very low mucosal folds (arrow). B. Infundibular neck of a laying ostrich hen showing longitudinal and oblique tall mucosal folds (black arrows); with short ones in-between (white arrows). C. magnal folds of a 72-month-old ostrich hen (arrows); D. Mucosal folds of magnum of 120-month-old ostrich (arrows).

laying hens (72 month-old) appeared as a rough surface, which gradually changed to low mucosal folds caudally (Fig. 1B). These folds gradually increased in height towards the tubular part. Some mucosal folds were longitudinally branched along its length and converged toward the abdominal orifice of the oviduct. The tubal part was a short, less convoluted tube. It measured 8.0 to 11 cm in length, 3.0 to 4.0 cm in width in the laying hens, and 3.0 to 5.5 cm in length, 1.5 to 2.0 cm in width in the pre-laying (36–42 month-old) ones. Their mucosal folds were arranged longitudinally with some oblique ones. Some short folds were

located in between the taller ones (Fig. 1C). They measured 2.0 to 4.0 mm in height.

The magnum was the longest and the most flexuous part of the oviduct. In laying hens (72 month-old) it measured from 53 to 58 cm in length and 4.5 to 10 cm in width. In pre-laying hens (36–42 month-old), the magnum length ranged from 31 to 43 cm and its width was 2.0 to 3.5 cm. The wall of the magnum was relatively thick. There were about 35 to 44 well developed primary longitudinally oriented folds. The free borders of these folds were wavy. From both sides of the tallest folds, other folds were extended

(Fig. 1C). Most of these folds measured 4.0 to 7.0 mm in height with low folds located among them. In 10-year-old layers, the folds became more tortuous, voluminous and higher than those of the previous ages (Fig. 1D).

Histology of the infundibulum and the magnum

In immature birds (8–10 months), the infundibular mucosa was folded. Some folds were short and nearly pyramidal in shape and most of them were tall, with narrow basal attached ends with partially divided broad rounded apices. The submucosa formed the cores of the folds (Fig. 2A). With the advancing of age (15–

month-old) the mucosal folds increased in size and branching, showing primary and secondary folds with many shallow indentations on their surfaces (Fig. 2C). The lining epithelium of the infundibulum was formed mainly of ciliated pseudo-stratified columnar and/or simple colum-nar type at the bases of the folds (Fig. 2B). The tunica muscularis in 10-month-old ostriches was less differentiated, but in 15-month-old, the muscular coat became more developed and consisted of inner circular strands and outer longitudinal layer of smooth muscle fibres.

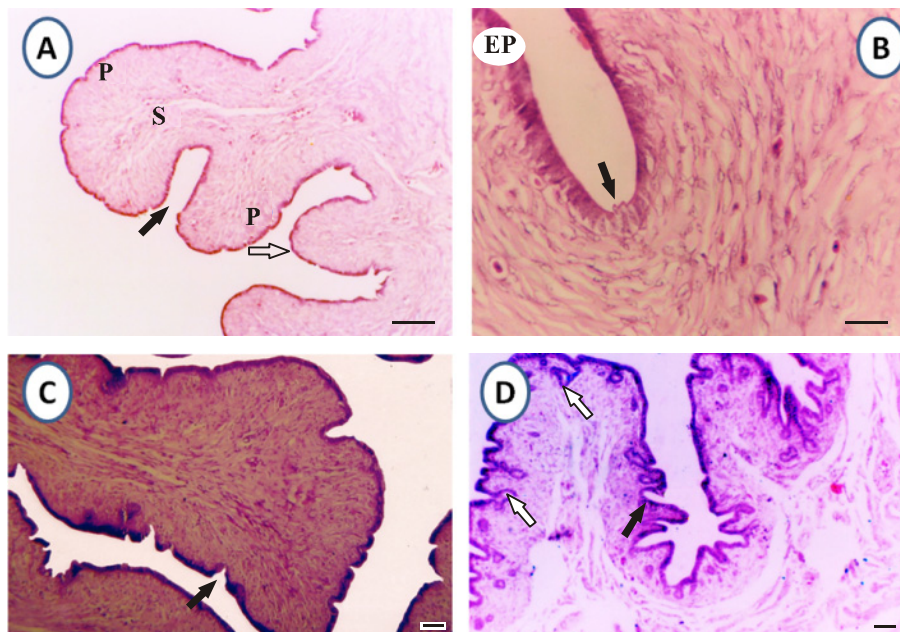In pre-laying birds (36–42 month-old), the infundibulum was differentiated

Fig. 2. Different developmental stages of ostrich infundibulum. A. 8–10 month-old chicks showed tall divided mucosal fold (black arrow) and short undivided ones (white arrow). The core of mucosal fold was divided into lamina propria (P) and submucosa (S); B. pseudostratified columnar epithelium (EP) with simple columnar cells lining glandular crypts (black arrow). C. In 15 month-old chicks, the infundibulum has several indentations (black arrow). D. A 36 month-old ostrich showing primary mucosal folds carrying secondary ones (black arrow) and surface oviductal tubular glands (white arrows). H&E, bar=20 μm.

and subdivided into an infundibular funnel toward the ovary, and a caudal tubal part. The mucosa of the infundibular funnel had short, broad highly branched mucosal folds carrying numerous small secondary folds and/or small invaginations. The infundibular funnel was lined with ciliated simple columnar epithelium. Meanwhile, the infundibular tubal part (neck) had a thicker wall than that of the funnel part. The mucosa of the infundibular neck was characterised by the presence of tall and short primary folds exhibiting several invaginations, which nearly occupied the whole lumen. The surface epithelium was formed of ciliated pseudostratified columnar type, in the bases of the folds; the surface epithelium was of simple columnar variety. Deeply and in-between the bases of the folds, the lining epithelium showed several tubular invaginations (Fig. 2D), which terminated with branched and unbranched glandular buds. The propria contained simple branched tubular glands, lined with columnar or pyramidal cells.

In laying hens (72 month-old), the mucosa of infundibular funnel gave short, broad and highly branched mucosal folds carrying secondary and some tertiary ones with short primary folds in-between (Fig. 3A). The infundibular funnel was lined with tall pseudostratified ciliated columnar epithelium (Fig. 3B). The bases of the glandular crypts were lined with tall ciliated columnar cells (Fig. 3C). The lamina propria consisted of collagen fibres and was free of glands.

The mucosa of the infundibular neck was characterised by the presence of long, curved and branched mucosal folds (Fig. 4A). These folds carried some secondary and tertiary ones. They occupied most of the lumen. The folds were taller than these of the infundibular funnel. The lining epithelium was built of a tall
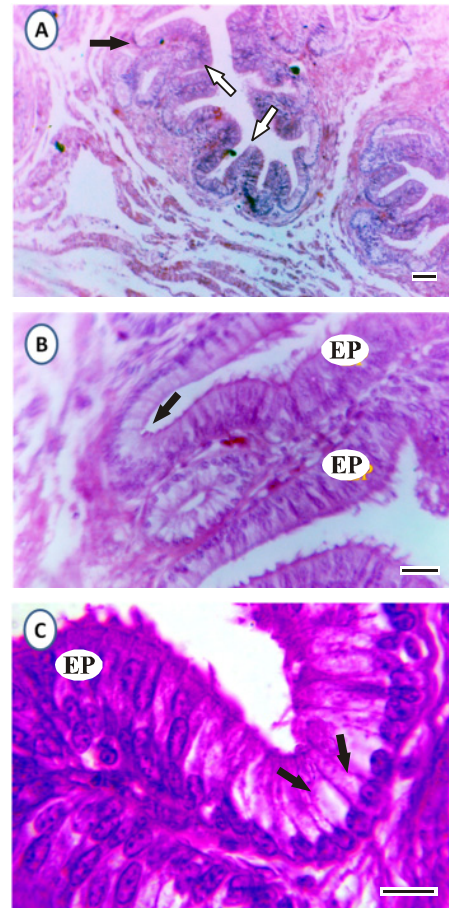

Fig. 3. A. Highly branched mucosal folds (white arrows) and glandular crypts (black arrow) in the propria of infundibular funnel of a 72-month-old ostrich hen; B. Ciliated pseudostratified columnar epithelium (EP) with less ciliated glandular crypts in the bottom (arrow); C. Crypts lined with tall columnar cells (arrows) and surface epithelium of the tall ciliated pseudostratified columnar type (EP). H&E, bar=20 μm.

ciliated pseudostratified columnar variety (Fig. 4D). Most of the lining cells possessed darkly stained basophilic granules within their supra nuclear
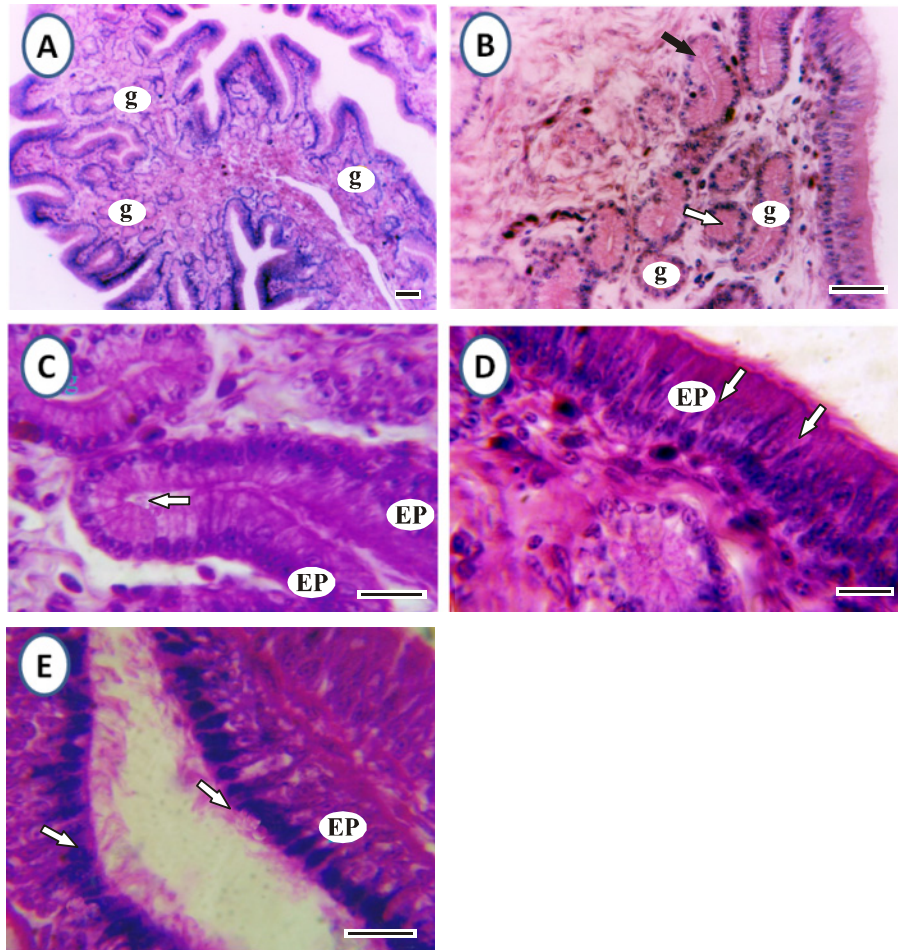
Fig. 4. A. Branched mucosal folds occupied by glandular tubules (g). B. Proprial glands (g) lined with columnar (black arrow) or pyramidal cells (white arrow). C. Tall ciliated pseudostratified columnar (EP) and tall columnar cells (arrow) in bottom of crypts. D. Goblet cells (arrows) in-between surface epithelium (EP); E. Infundibular neck epithelium (EP) has large coarse basophilic granules (arrows) in supranuclear regions. H&E, bar=20 μm.

regions (Fig. 4E). The bases of the glandular crypts were lined with tall columnar cells (Fig. 4C). The propria was formed of delicate connective tissue and occupied by tubular glands. These glands were lined with pyramidal or tall columnar cells (Fig. 4C, D). The cytoplasm contained secretory acidophilic granules at the luminal portion of the cells (Fig. 4D).

Toward the magnum, the glandular structures increased in the propria of the mucosal folds. The connective tissue among the glands was mainly formed of

collagenic fibres with numerous blood capillaries (Fig. 5A). The tunica muscularis had inner circular and outer longitudinal layers of smooth muscle fibres.

Histochemically, the lining epithelium of the infundibulum in immature birds reacted negatively to PAS. A strong PAS-positive reaction was only shown through the basal lamina of the lining epithelium (Fig. 5B)

In laying hens (72 month-old), the surface epithelium of the infundibular funnel and its ciliary zone showed a negative PAS reaction. The supranuclear regions of the surface epithelium and most of the cytoplasm of the glandular tubules at the infundibular neck exhibited a strong PAS positive reaction (Fig. 5C).

In some glandular secretory units, the luminal borders gave weak PAS positive reaction. The most apical part of the surface epithelium of the infundibular neck gave strong alcianophilic reaction at pH 2.5 (Fig. 5D).

The mucosa of the magnum in 8–10 month-old chicks was characterised by the presence of primary longitudinally oriented folds (Fig. 6A). The surface epithelium was of the simple columnar type. At 15 months of age the lining epithelium was formed of short ciliated pseudostratified columnar and low columnar cells. In addition, the lining epithelium of the mucosal folds started to invaginate into the propria to form the glandular buds and tubules. The lamina propria in immature
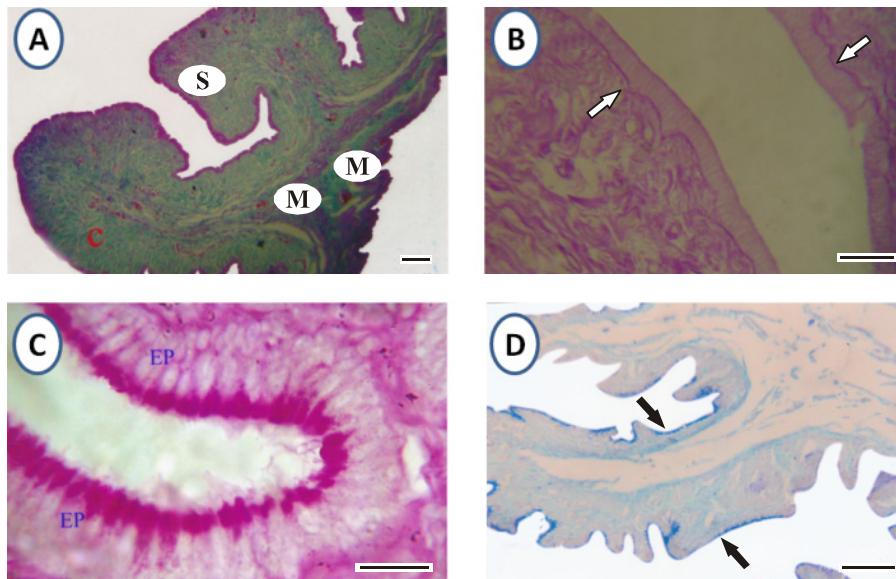

Fig. 5. Histochemical traits of ostrich infundibulum at different developmental ages A. Immature ostrich chick's infundibulum showed collagenic fibres in the propria and submucosa (S), and a thin muscular coat (M). Crossmon's trichrome, bar=20 μm. B, C. PAS positive basement membrane (arrows). In immature ostrich chicks and in laying hens infundibular neck epithelium was PAS-positive in apices and tall columnar cells-lined bases of glandular crypts (arrows), respectively. PAS, bar 20=μm. D. Infundibular neck – alcianophilic substances in the epithelium covering folds (arrows), mostly absent in glandular crypts. Alcian blue pH 2.5, bar=100 μm.
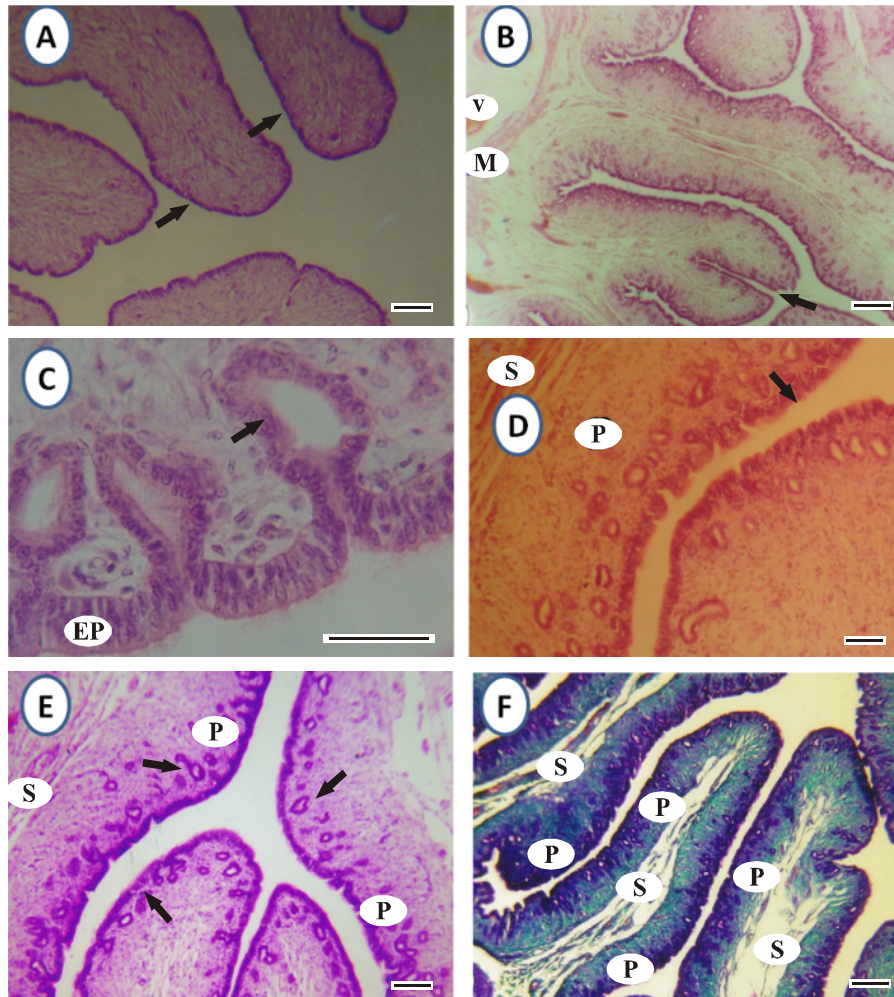
Fig. 6. Ostrich magnum. A. Primary mucosal folds in 8–10 month-old chicks (arrows), H&E. B. Branched primary mucosal folds in 36-month-old pre-laying ostrich hens (arrow), clear muscular coat (M), H&E. C. Surface epithelium (EP) connected to glandular tubules (arrow), H&E. D. Cross section in the most apical free end of mucosal fold (arrow), propria (P) and submucosa (S), H&E. E. Surface oviductal glands (arrows) in propria (P) and fine loose connective tissue in submucosa (S), H&E. F. Lamina propria (P) and delicate collagenic connective tissue in submucosa (S). Crossmon's trichrome, bar=50 μm.

birds was formed of cellular connective tissue with numerous branched blood capillaries. The glandular buds began to appear at both ages.

Tunica muscularis of the magnum was formed of circularly arranged intermingled smooth muscle fibres and the magnal wall was externally covered with tunica serosa.
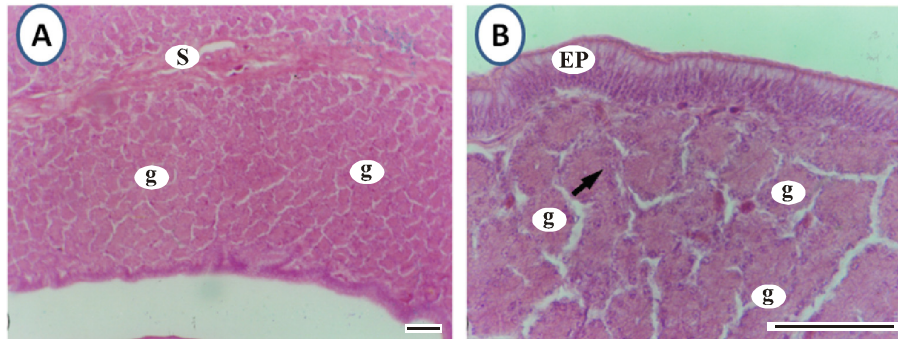
Fig. 7. Magnum of laying ostrich hens. A. Mucosal fold filled with proprial glands (g) leaving fine submucosal connective tissue strand (S) in-between. B. High magnification to (A) showing surface epithelium (EP) and proprial glands (g) filled with acidophilic secretory materials (arrow). H&E, bar=50 μm.
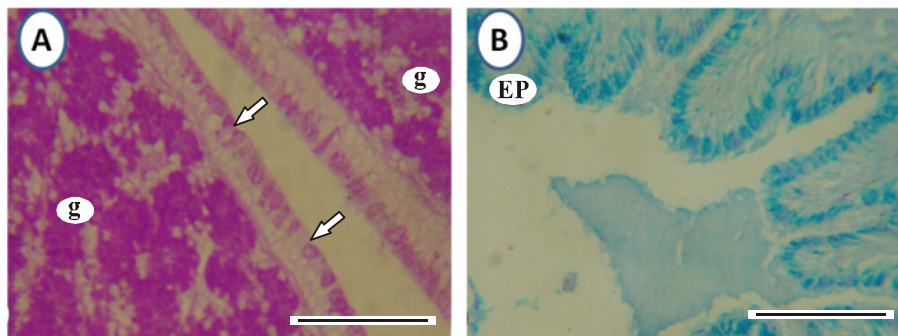

Fig. 8. Histochemical traits of magnum in a laying ostrich. A. Strong PAS positive staining in the epithelium (arrow) and glands (g) in a laying ostrich hen. B. Strong alcianophilic positive substances in the surface epithelium only (EP) and negative reaction of glands to alcian blue pH 2.5. PAS, bar=50 μm.

In the pre-laying birds (36–42 months of age), the magnal mucosa was characterised by the presence of long primary mucosal folds which sometimes appeared branched. The mucosa occupied most of the magnal wall thickness (Fig. 6B). The lining epithelium was of the ciliated pseudostratified columnar type (Fig. 6C). The glandular crypts were lined with the same epithelial lining as the surface epithelium.

The core of mucosal folds was formed of lamina propria on both sides of the mucosal folds (Fig. 6F). Numerous tu-

bular and branched tubular glands were distributed through the lamina propria under the surface epithelium (Fig. 6D). Some glands opened onto the surface of the mucosal folds by short ducts (Fig. 6E). The tubular glands were lined with a single layer of cuboidal cells.

In laying hens (60–72 month-old), the magnum was the most coiled and longest part of the oviduct. It was characterised by its superficial vascularity. The magnal mucosa gave rise to tall and broadleaf-like primary folds. These folds occupied

Table 1. Variations in the height of the folds (μm) in relation to age of each region of the oviduct. Data are presented as mean ± SEM

Age groups	Region of the oviduct				
	Infundibulum	Magnum	Isthmus	Uterus	Vagina
8 months	549.80 ± 105.23[b]	942.50 ± 178.57[b]	664.58± 29.10[c]	825.3± 73.32[b]	435.00± 62.09[c]
15 months	779.38 ± 37.14[ab]	1510.42 ± 519.92[b]	785.33± 51.02[c]	1184.2± 76.42[b]	882.08± 60.42[c]
36–42 months	453.05 ± 32.05[ab]	1791.67± 239.84[b]	2687.50± 173.33[b]	1027.1± 57.44[b]	2687.50± 476.73[b]
72 months	1075.41± 183.81[a]	3404.17± 295.92[a]	3941.67± 463.35[a]	8710.0± 314.03[a]	4694.17± 438.57[a]

Means within each column bearing different superscripts are significant at P≤0.05.

Table 2. Variations in the size of the glands (μm) in the lamina propria in different oviduct regions at different ages. Data are presented as mean ± SEM

Age group	Region of the oviduct			
	Infundibulum	Magnum	Isthmus	Uterus
8 months	0.00±0.00[c]	0.00±0.00[c]	0.00±0.00[c]	0.00±0.00[d]
15 months	0.00±0.00[c]	11.38±1.55[b]	0.00±0.00[c]	8.40±0.40[c]
36–42 months	12.93±1.26[b]	11.37±0.65[b]	$12.33 \pm 6.667E^{-02b}$	15.03±1.70[b]
60–72 months	24.37±2.47[a]	31.10±1.96[a]	28.52±1.86[a]	21.28±1.68[a]

Means within each column bearing different superscripts are significant at P≤0.05.

most of the wall thickness. The lining epithelium was of the tall ciliated pseudostratified columnar variety containing both ciliated and goblet cells. The mucosal thickness of the magnum was greater than that of the infundibular neck due to the massive proprial glands. The glands occupied most of the propria, opening on the epithelium covering the mucosal folds. In addition, the magnal glands were lined with pyramidal cells with vesicular basally located nuclei. The cytoplasm was filled with acidophilic secretory matter (Fig. 7A, B). The submucosa was fibrous, centrally located in the folds (Fig. 7A). The tunica muscularis was formed of two layers namely a thin inner circular and an outer longitudinal smooth muscle layer.

Histochemically, the apical regions of the goblet cells lining the magnum showed PAS positive stained matter (Fig. 8A) and ciliated non-secretory cells were PAS-negative in the laying hens. The surface epithelium covering folds and the glandular crypts exhibited strong alciano-philic reaction in the supranuclear regions in the goblet cells (Fig. 8B). Most of the

glandular epithelium gave strong PAS-positive reaction (Fig. 8A). In contrast, the magnal glands were alcian blue negative (Fig. 8B).

Morphometry of the infundibulum and magnum

The different measurements for the infundibulum and magnum showed that the infundibular and magnal mucosal folds increased more in height, volume and branching in mature ostriches more than in immature ones as compared with other oviduct regions (Table 1). Moreover, the magnal proprial glands reached the maximum size in comparison with other oviduct regions glands (Table 2).

DISCUSSION

The current work confirmed that the oviduct in ostriches was rather similar to that of other domestic birds, formed of five different regions: infundibulum, magnum, isthmus, uterus, and vagina. Our findings coincided with those of Aitken (1971); Hodges (1974); Nickel *et al.* (1977); Dellmann & Eurell (1998) in domestic fowls; Bakst & Howarth (1975) in white leghorn hens, and Elbargeesy (1990) in sexually mature turkeys.

The mucosal folds of the infundibulum in the present work were branched and ran longitudinally, obliquely and/or tortuously. This fact was in agreement with Dellman & Eurell (1998) in domestic fowl but in the same species, Nickel *et al.* (1977) added that the infundibular mucosal folds had a slightly spiral course.

The present study revealed that the ultrastructure of the surface epithelium showed two types of cells, ciliated and non ciliated granular cells, as also reported by Muwazi *et al.* (1982) and Saber *et*

al. (2010) in ostriches and El-Bargeesy (1990) in hens and Fertuck & Newstead (1970) in quails.

The surface epithelium of the immature oviduct was composed of ciliated and non-ciliated cells. The cilia increased in number and density toward the vagina. Similar findings were shown in the immature chicks.

Fujii (1981) assumed that the mode of ciliation varied in each oviductal segment depending on the stimulatory effect of ovarian hormones. In addition, the rate of ciliation of the oviduct of chicks was correlated to the estrogen administration (Anderson & Hein, 1976). Our current work revealed that the lining epithelium of the immature ostriches was formed from simple columnar and pseudostratified columnar cell varieties. The results were similar with those in fayoumi chicks (Fouad, 1970); Pekin ducklings (El-Habbak, 1990); sexually mature turkeys (Elbargeesy, 1990); in one day old chicks (Kelany *et al.*, 1993) and 1–3 weeks old quail chicks (Sayed, 2000).

The oviduct developed slowly until the age of pre-layers, where a marked increase in the length, thickness and diameter of the oviduct, as well as the height of the epithelium and the mucosal folds appeared in laying hens as reported by Kelany *et al.* (1993) in chickens.

In white leghorn and Rhode Island hens Richardson (1935) found that during the egg formation cycle, the goblet cells were transformed into ciliated cells or vice versa. In white leghorn hybrid hens, however, no evidence for aphasic transformation between goblet and ciliated cells was reported (El-Bargeesy, 1990).

The lamina propria of the infundibular funnel had no mucosal glands, as also reported by Muwazi *et al.* (1982) in mature ostriches, by Vernerová-Procház-

ková (1971) and Hodges (1974) in domestic fowls, by Das & Biswal (1968) in domestic ducks. Our data supported also the results in sexually mature turkeys (Elbargeesy, 1990), sexually mature ducks (El-Habbak, 1990) and sexually mature quails (Sayed, 2000). The infundibular neck had mucosal folds which were negatively stained with alcian blue as observed in Pekin ducks by El-Habbak (1990). Moreover, he observed that the proprial glands in the infundibulum were devoid of any detectable amounts of acid mucopolysaccarides. This suggested that these proprial glands were involved in the production of inorganic matrix of the egg (Breen & DeBruyn, 1969). In immature ostrich chicks with inactive ovary the magnal mucosa contained longitudinally directed furrows and folds, while with active ovaries.

The mucosal folds of magnum of pre-layers were longitudinally oriented. With progression of age synchronised with heavy egg production (laying ostrich hens), the folds appeared to be extremely tortuous or heavy. The total number of the folds per cross section of the magnum ranged from 35 to 44. According to published data, in adult chickens the primary folds were 22 (Mclelland, 1990) and in domestic hens were 15 to 22 (Nickel *et al.*, 1977). This difference in fold number could be attributed to species difference.

The present work showed that the mucosal folds in the magnum were mostly of the primary type, similar observations were made by Aitken (1971) in domestic hens and Mclelland (1990) in adult chickens. Our results were nearly the same as those of Bakst & Howarth (1975) who reported that the primary folds were present with little evidence for secondary ones in white leghorn hens. However, Hodges (1974) stated that the magnum of domestic hens carries primary, secondary and tertiary folds.

In the magnum the subepithelial connective tissue differentiated into lamina propria and submucosa in the immature ostrich females. A well developed lamina propria was present in the pre-laying and laying ostrich hens and occupied with glandular unites, and the submucosal folds, containing numerous blood vessels. However in domestic ducks (Das & Biswal, 1968) and in mature ostrich hens (Muwazi *et al.*, 1982) no distinct submucosa was reproted in the infundibulum.

Bradley & Grahame (1960) discussed this theory in the epithelium of the magnum, which varied in the height according to the phase of secretory activity previously confirmed by Surface (1912) who reported that two types of cells alternate one with the other. During the different phases of the egg formation cycle, goblet or non-ciliated cells could predominate, which means that before passages of the egg yolk through the magnum, the goblet cells appeared to predominate and the ciliated cells were obscured. After passage of the egg yolk, the ciliated cells predominated over goblet cells and the surface epithelium appeared ciliated.

The height of surface epithelium of the magnum was shorter in the immature ostriches (7.45 μm). It increased gradually to reach its maximum (21.3 μm) in laying ostrich hens. In comparison with results of Richardson (1935), the height of magnal epithelium measured about 30 μm before the egg passes the magnum region. We suggested that this was due to the packed goblet cells with secretory materials. After the magnum discharged its secretion, the ciliated cells predominated and the surface epithelium measured 18 μm in height.

In the mature ostriches we found strong PAS positive substances in the apical part of the lining epithelium and the lamina propria of the infundibulum, as well as the alcianophilic substances in the supranuclear regions of the lining epithelium, revealing the activity of infundibular neck in the formation of first albumen layer (Scott & Huang, 1940). Also, these reactions were stronger toward the magnum which coincides with the findings of Aitken & Johnston (1963) in thronber 505 hybrid hens. In white leghorn hens (Solomon, 1971), in laying hens (Guzsal, 1968; Solomon, 1971) in fayoumi fowl (Fouad, 1970) the infundibulum deposited the first albumen layer on the ovum, which was completed on the ova in the magnum (Conard & Philips, 1938).

The glandular structures of the ostrich oviduct included two main cell types. The first was represented by the mucus secreting columnar cells (goblet cells) which were found all over the oviductal epithelium. They were numerous in the magnum of chickens (Solomon, 1971). The second type was represented by multicellular glands, which include the glandular crypts and glandular tubules described in domestic hens (Richardson, 1935; Dellman & Eurell, 1998), in domestic fowl (Aitken & Johnston, 1963), in sexually mature turkeys (El-Bargeesy, 1990). Also we observed that all proprial glands in the infundibular neck and magnum reacted negatively with alcian blue (pH 2.5). These observations go hand to hand with those of El-Habbak (1990) in pekin ducks, who reported that the proprial glands were devoid of any detectable amounts of acid mucopolysaccharides. This suggested that these glands were involved only in the production of inorganic matrix of the egg (Breen & DeBruyen, 1969).

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